GEOARCHAEOLOGICAL IMPLICATIONS OF HOLOCENE LANDSCAPE EVOLUTION IN THE LOS VAQUEROS AREA OF EASTERN CONTRA COSTA COUNTY, CALIFORNIA

by

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ABSTRACT

Archaeologists have long been aware that many archaeological sites in California have been buried by natural geological processes. Buried sites are generally discovered after being inadvertently exposed by erosion or mechanical excavation, and only rarely are they identified in advance by archaeological investigations. The significance of buried sites has yet to be fully appreciated or systematically investigated in California, despite a number of innovative studies that have focused on the problem of buried sites in other parts of North America. Given the high level of geologic activity in the state, there is a need for geoarchaeological studies that will assist archaeologists and cultural resources managers in locating and interpreting those portions of California's archaeological record that remain buried.

This study proposes a method of locating buried archaeological resources that combines the discipline of geoarchaeology with the perspective of landscape evolution. The study was designed to estimate the potential for buried archaeological resources by identifying buried land surfaces (paleosols) that were available for human occupation in the past. The findings of this study are important for understanding the influence of landscape evolution on the archaeological record of eastern Contra Costa County, and for predicting the location of buried archaeological resources in the region.

Since many valleys in Central California contain relatively recent alluvium, it was hypothesized that alluviation may have buried land surfaces that were once available for human occupation in the valleys of the Los Vaqueros area. A subsurface survey program was developed to locate buried land surfaces and estimate the potential for buried archaeological resources in the valleys. The survey was designed: (1) to test the accuracy of previously published geological information; (2) to identify and date buried paleosols and/or watercourses that could have been used by people in the past; (3) to identify and date buried archaeological materials; and (4) to determine the sequence of landform-sediment assemblages in separate valleys of eastern Contra Costa County.

The potential for buried archaeological deposits in a given area were determined by: (1) the presence or absence of a paleosol buried during the Holocene; (2) the preservation or erosion of the surface of a buried paleosol; (3) the interval of time (landform stability) represented by a paleosol; (4) the presence or absence of a present or former watercourse; and (5) the proximity of a buried paleosol to a present or former watercourse.

One or more buried Holocene paleosols were identified in five of the six valleys surveyed by this study. The paleosols were found to range in depth from 70 cm to 440 cm below the present ground surface, with an average depth of 164 cm. The valleys that contained these paleosols were estimated to have a low to moderate potential for containing buried archaeological resources. One location (CA-CCO-637) was found to have a high potential for buried archaeological resources, due to the occurrence of archaeological materials associated with a buried paleosol. The remaining areas were estimated to lack the potential for containing buried archaeological resources.

This study found that the timing and extent of landscape evolution have exerted a profound influence on the structure of the archaeological record in eastern Contra Costa County. Extended periods of floodplain stability and soil development encouraged human landuse in the valleys, which promoted the formation of archaeological sites. Shorter episodes of floodplain instability temporarily discouraged or disrupted human occupation in many valleys, and buried or destroyed evidence of previous occupations. The alternation between stable and unstable landform processes has resulted in the differential preservation and/or visibility of archaeological materials associated with the valley floodplains.

Comparisons of alluvial sequences from valleys in eastern and western Contra Costa County demonstrate that they share roughly synchronous depositional histories. Based on regional correlations, the depositional sequence identified by this study appears to reflect a series of climatically induced landscape changes that occurred throughout much of Central California. Similarities in the age of the alluvial sequences found in widely separate valleys suggest that geological processes have also structured the temporal range and spatial distribution of archaeological materials in these valleys.

This study demonstrates that prehistoric settlement, subsistence, and demographic patterns cannot be inferred strictly from the distribution of sites at the surface of alluvial valleys. Regional patterns of erosion and deposition have buried significant portions of the archaeological record in a way that can be identified, dated, and to some extent predicted in Central California. Given these findings, the timing and magnitude of Holocene landscape change should be evaluated as an integral factor in interpreting the apparent significance of archaeological site distribution patterns in this, and other regions of California.

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CHAPTER I

INTRODUCTION

Purpose of Study

After more than a century of archaeological inquiry, the significance of buried sites have yet to be fully appreciated or systematically investigated in California. While archaeologists working in the state have long been aware that many sites are buried, most buried sites are not intentionally discovered but are found after being accidentally exposed by natural erosion or mechanical earth moving (Heizer 1948, 1950a, 1950b; 1952; Cook and Elsasser 1956). Although geoarchaeological studies have been used to successfully address the issue of buried sites elsewhere in North America, such studies have only recently been applied in California. As the landscape is forever altered by human development, there is an urgent need for systematic geoarchaeological studies that can assist archaeologists and cultural resources managers in locating and interpreting those portions of the archaeological record that are buried.

This study proposes a method for locating buried archaeological resources that combine the discipline of geoarchaeology with the perspective of landscape evolution. The study was designed to estimate the potential for buried archaeological resources by identifying buried land surfaces (paleosols) that were available for human occupation in the past. This study was performed in eastern Contra Costa County prior to the construction of a water conveyance system for the Los Vaqueros Project, sponsored by the Contra Costa Water District (CCWD). The findings of this study are important for understanding the influence of landscape evolution on the region's archaeological record, and for predicting the location of buried archaeological resources in other parts of California.

<u>The Los Vaqueros Project Area</u>

The Los Vaqueros Project area is located within eastern Contra Costa County and a small part of northeastern Alameda County, approximately 64 km (40 miles) northeast of San Francisco, and 40 km (25 miles) west of Stockton in Central California. Smaller communities located within 16 km (10 miles) of the project area include Livermore to the south, and Brentwood and Byron to the east. A portion of the project area is intersected by the Mt. Diablo Base Line at point 17.6 km (11 miles) due east of Mt. Diablo (Figure 1).

The area, situated in the northern Diablo Ranges along the western edge of the Central Valley and the Sacramento-San Joaquin Delta, is composed of a series of low-lying foothills and northeast-trending valleys that drain into the Central Valley and delta. The foothills range in elevation from about 30 m to 335 m (100-1100 feet) above mean sea level. The lower eastern hills are dominated by grasslands while the higher western slopes are covered by oak woodland-savanna and patches of chaparral, marking a contact zone between the foothill woodland and valley grassland plant communities. Riparian plant communities are found along the higher order stream channels in the area (Simons 1982a).

The Los Vaqueros Project is designed to improve water quality of the CCWD service area by storing higher quality water from the San Joaquin Delta in an inland reservoir for use when water quality is seasonally low. Plans call for water from the delta to be pumped through a conveyance system and stored in the Los Vaqueros reservoir located in the upper Kellogg Creek drainage. Water will be released as needed from storage in the reservoir and conveyed using the same system to the Neroly blending facility near Antioch (Figure 1).

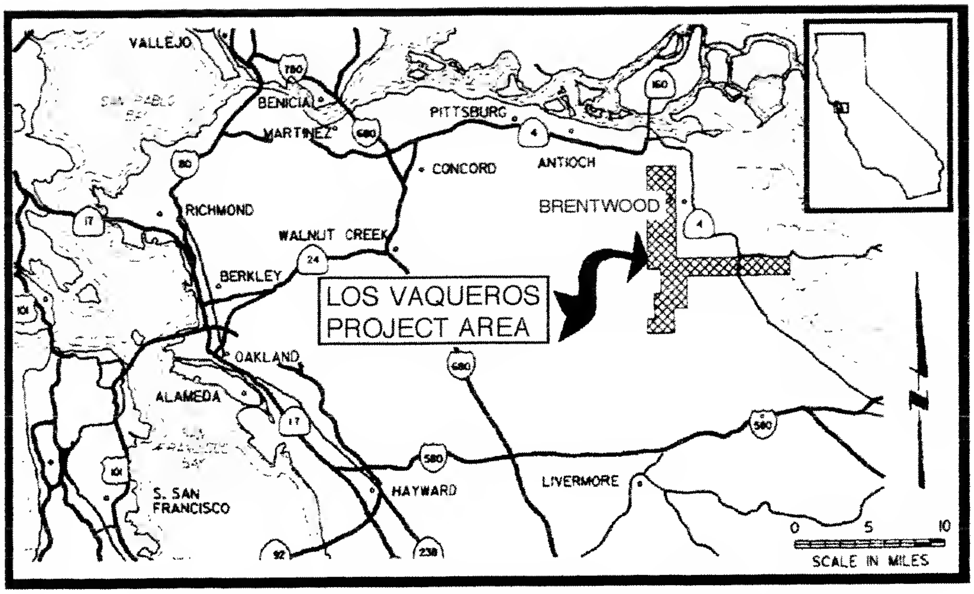
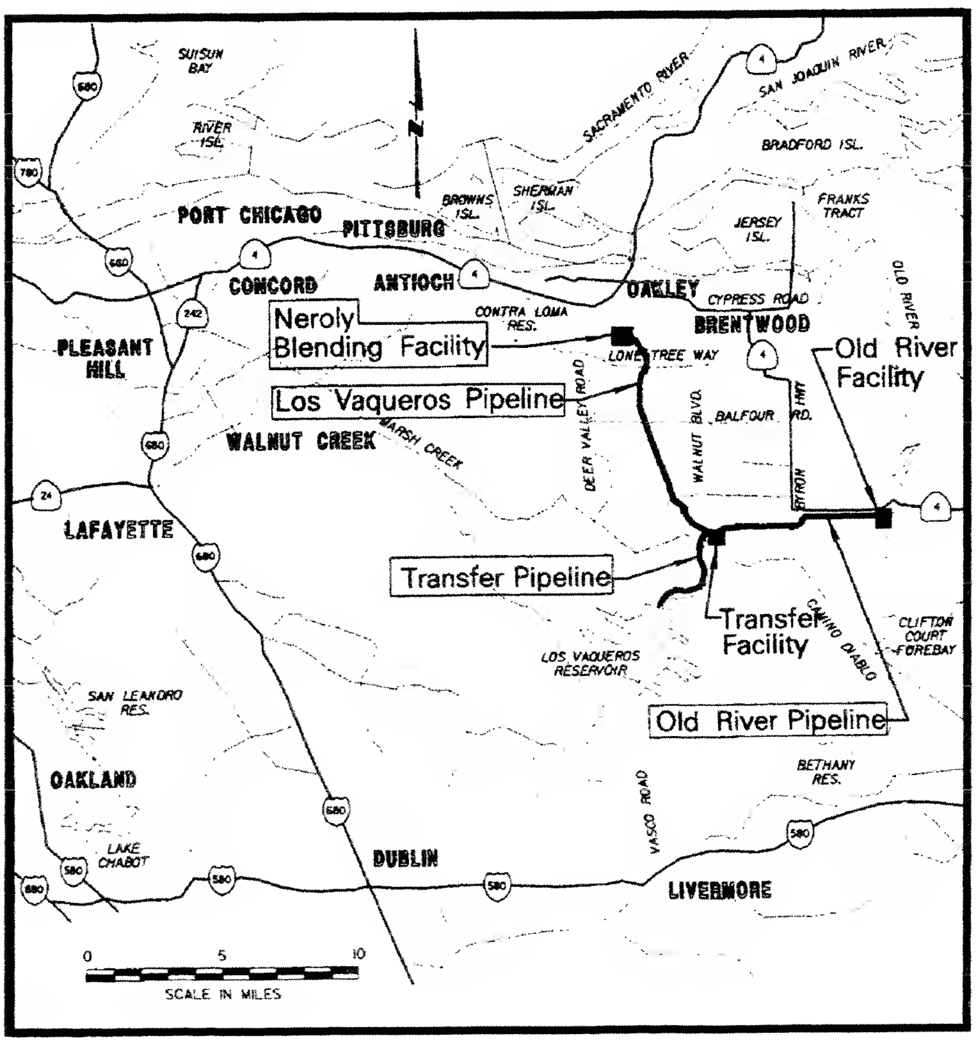


FIGURE 1. MAPS OF PROJECT AREA AND VICINITY



The project's water conveyance system will consist of three interconnected pipeline routes: the Old River route, the Transfer route, and the Los Vaqueros route. For the purposes of this study, the Pipeline Route refers to (1) the entire route of the proposed Transfer Pipeline that lies between the Los Vaqueros reservoir and the Transfer Facility; and (2) the entire route of the proposed Los Vaqueros Pipeline that lies between the Transfer Facility and the Neroly Blending Facility near Antioch, California (Figure 1). The total length of the Pipeline Route is approximately 20.8 km (13 miles) between the reservoir and the blending facility. For analytical and methodological reasons, this study did not include the Old River Pipeline, located between the Old River Pump Station and the Transfer Facility (see Chapter 4).

CHAPTER 2

GEOLOGICAL AND ARCHAEOLOGICAL OVERVIEW

Previous Geological Studies

An intensive literature search was conducted for studies that identify and/or discuss the geology, depositional history, and landscape evolution of landforms in Contra Costa County. The geology of the area has been mapped in limited detail by Atwater (1980, 1982); Brabb, Sonneman, and Switzer (1971); Dibblee (1980); Helley et al. (1979); Nilsen (1972); Preston (1965); and Wagner, Bortugno, and McJunkin (1990). The late Quaternary depositional history is addressed in general terms for portions of the area by Atwater (1980, 1982); and Helley et al. (1979). Surface soil and landform relationships in the county have been mapped and described in some detail by Carpenter and Cosby (1939); and Welch (1977). Regional studies that do evaluate late Quaternary landscape evolution are generally restricted to the Sacramento-San Joaquin Delta area (Atwater 1979, 1980a, 1980b, 1982; Atwater et al. 1979; Shlemon and Begg 1975; Wells 1995).

Detailed geologic and geotechnical investigations for specific parts of the project area were conducted by: Department of Water Resources (1978); Earth Sciences Associates (1992); Geomatrix Consultants (1992); Leeds, Hill, and Jewett, Inc. (1970); Mark Group Engineers & Geologists, Inc. (1992); and Woodward-Clyde Consultants (1989). The data generated by these studies is generally intended for the purposes of engineering and construction, and do not represent significant contributions to the late Quaternary geology of the area. However, these studies often distinguish alluvial, colluvial, and bedrock deposit types.

Despite the number of studies conducted in the area, there are very few detailed examinations of late Quaternary deposits or attempts to reconstruct the geomorphic history of the area's landforms. The existing studies are preliminary and have not been undertaken with systematic sampling or reporting procedures. Comparison between these studies shows that the reported age, type, distribution of deposits in the valleys may vary greatly from one to the next. Age estimates for deposits in the valleys are supported by few dated samples. The lack of an accurately regional alluvial sequence posed a problem for this study, because the potential for buried archaeological deposits are determined in part by the age range of the deposits.

Geomorphic History

Previous studies indicate that Central California has undergone a number of significant environmental changes since the time that people may have first inhabited the region during the late Pleistocene. Most of what is known about the region's geomorphic history during the last 15,000 years is related to geologic studies of the San Francisco Bay, Sacramento-San Joaquin Delta, and surrounding lowlands.

During the middle to late Pleistocene, San Francisco Bay was a valley that carried runoff from the Central Valley and other parts of the bay through an inland drainage before entering the ocean near the Farallon Islands (Atwater, Hedel, and Helley 1977). At the end of the Pleistocene, the melting of continental ice masses caused a rapid rise in world-wide sea levels. Continued sea level rise in the Bay Area drowned many inland valleys during the early Holocene, which created a series of inland bays and tidal plains in their place (Figure 2). The expanding sea reached the western edge of the present delta-

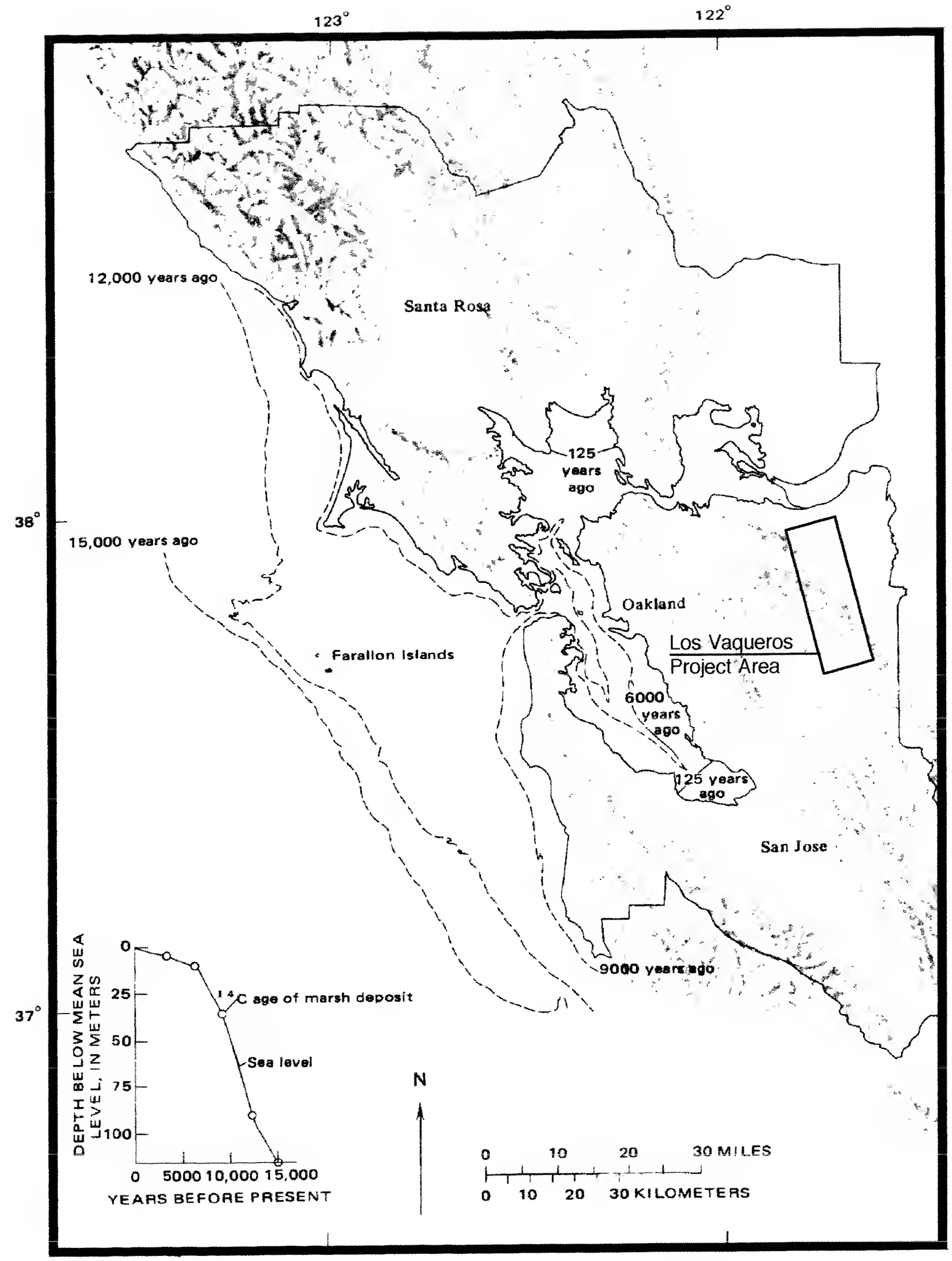


FIGURE 2. HOLOCENE SEA LEVEL RISE IN SAN FRANCISCO BAY AREA

(adapted from Helley et al. 1979: Fig. 12)

estuary about 7,000 years ago -- around the same time that the rate of sea level rise began to slow dramatically (Atwater 1977, 1980b; Shlemon and Begg 1975; Wells 1995). The decrease allowed sedimentation to keep pace with submergence rates, permitting extensive tidal marsh environments to become established in the delta-estuary during the middle Holocene as shown in Figure 3 (Atwater et al. 1979). The delta-estuary continued to increase in size due to ongoing decomposition, compaction, and subsidence of the intertidal deposits during the middle and late Holocene, and not because of subsequent sea level rise (Atwater 1977, 1979, 1980a; Shlemon and Begg 1975). By 1850, tidal marshes covered twice as much inland area as all the water in the bay and delta combined (Atwater et al. 1979). As a whole, the Sacramento-San Joaquin Delta-estuary is a relatively recent feature of the landscape that has evolved to its present configuration over the last 7,000 years.

Stream channels draining the region were forced to adjust to progressively higher base levels as the sea rose, causing the lower reaches to become partially filled with sediment (Helley et al. 1979). In an attempt to maintain their channels, streams responded by shifting position and by avulsing sediments over their banks onto surrounding floodplains. This led to the formation of an "alluvial apron around the bay plain and the extensive valleys of the region" that is graded to the present sea level and is generally no more than 7,000 years old (Helley et al. 1979:18). These changes represent a major period of the deposition as compared to the preceding period of non-deposition during the late Pleistocene and early Holocene. The older land surfaces around the Bay are, therefore, overlain by younger deposits that mark a significant stratigraphic contact in the region.

Although well-dated profiles are lacking, geologic mapping of the lowlands surrounding the Sacramento-San Joaquin Delta-estuary generally

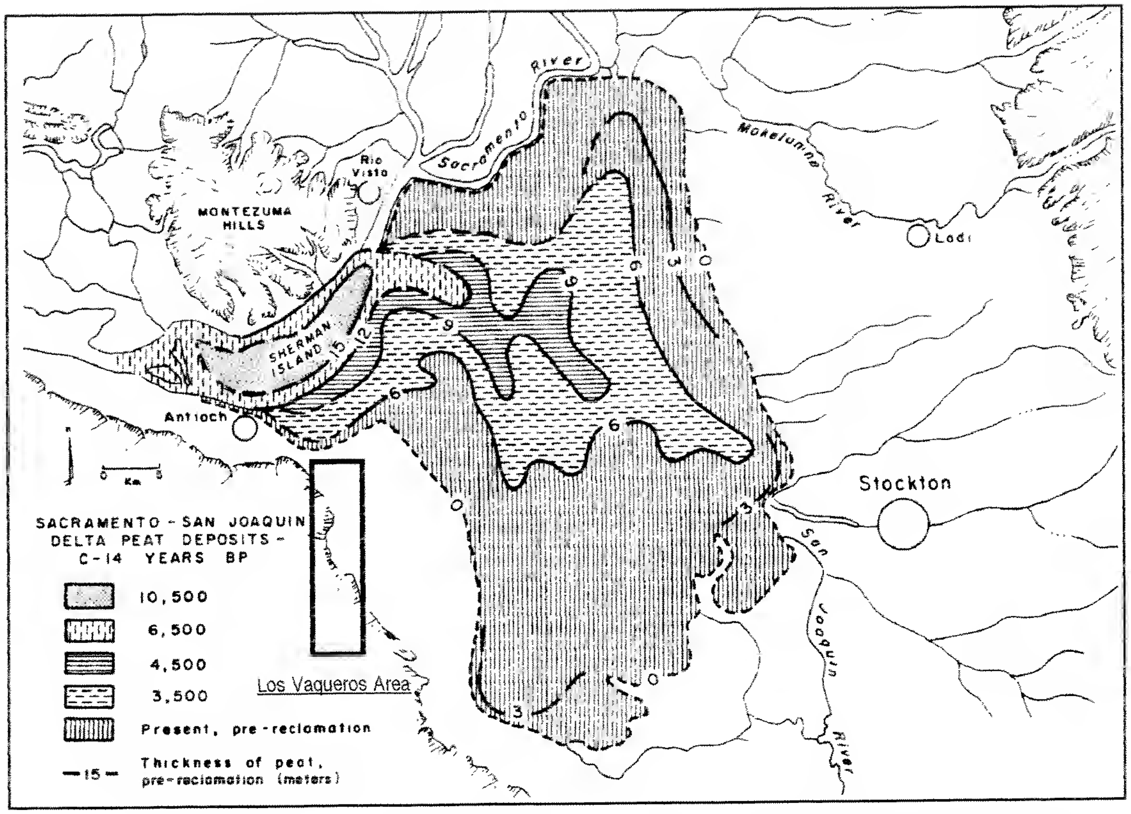


FIGURE 3. HOLOCENE SEA LEVEL RISE IN SACRAMENTO - SAN JOAQUIN DELTA AREA (adapted from Shlemon and Begg 1975: Figure 5)

corresponds with the sequence of changes outlined for the Bay Area. After a non-depositional period in the late Pleistocene and early Holocene, the lowlands of the Central Valley slowly filled with water, sediments, and marsh plants, thereby raising the baseline of stream and river channels entering the delta during the middle Holocene (Figure 3). Local channels responded by shifting their positions and depositing a significant amount of sediment over the surface of the previous floodplains. Large alluvial fans and prominent levee deposits were formed by channels such as Marsh, Kellogg, and Sand Creeks that drained into the delta from the southwest (Atwater 1982; Brabb, Sonneman, and Switzer 1971). In the Marsh Creek vicinity, these younger alluvial deposits

are estimated to range from late Pleistocene to late Holocene in age (Atwater 1982). The Holocene deposits range in thickness from 15.0 m near alluvial fan heads to 3.0 m near the delta and bay margins (Helley et al. 1979).

A few geological studies have evaluated the age and geomorphic history of alluvium filled valleys in the interior portions of Contra Costa County. These studies found that most of the interior valleys are partially filled with Holocene age alluvium that unconformably overlies older alluvium. Investigators recognized three distinct periods of alluvial filling (7800 B.P., 4800 B.P., and 1200 B.P.) and two significant periods of channel entrenchment in the middle and late Holocene (Rogers 1988; Pape 1973). The thickness of the Holocene fills in these valleys is judged to be at least 3.0 m to 4.5 m (Wigginton and Carey 1982:214), but may be as great as 30.0 m in some valleys (Pape 1973). In sum, these studies demonstrate that older land surfaces are buried by Holocene age alluvium in the lowland valley portions of the region. They also suggest that channel migration and entrenchment has removed and redeposited the buried land surfaces in some areas.

Cultural Sequence and Settlement Pattern

Except for test excavations reported by Stewart and Villamaire (1995), and a preliminary report of excavations by Meyer and Rosenthal (1996), there have been no formal archaeological excavations in the Los Vaqueros Project area. Hypotheses regarding the area's prehistory were based on archaeological studies from the surrounding regions of Central California. Synthetic reconstruction's of the project area's prehistory have been developed by Fredrickson (1982), Simons (1982b), Eidsness (1986), and Bramlette et al. (1988). Expectations regarding the sequence and pattern of prehistoric settlement of the area are based on the distribution of archaeological

components that are less than 4,000 years old. As already noted, the evidence of earlier human habitation in the region is generally assumed to be deeply buried by alluvium (Eidsness 1986; Fredrickson 1980; Moratto 1984). Due to the lack information, "little can be said of early- to mid-Holocene archaeology in the Central Valley" (Moratto 1984:215). The following review considers cultural chronology and settlement pattern as two factors that may determine the location of buried sites.

Researchers generally agree that people occupied several parts of California 12,000-8,000 B.P. years ago during the Paleoindian Period (Moratto 1984). Early occupation in this period is recognized on the basis of fluted projectile points and crescent-shaped bifaces that together mark the "Fluted Point Tradition." According to Moratto (1984), the Paleo/Archaic transition is marked by the appearance of ovate and stemmed point types of the "Western Pluvial Lakes Tradition." Evidence of both traditions is most often found along the shores of ancient lakes or marshes. Artifacts of this type have been found at Borax Lake in the Northern Coast Ranges, and Tulare Lake and Buena Vista Lake in the southern San Joaquin Valley. A crescent and fluted point were reportedly found in northern San Joaquin County near Tracy Lake (Moratto 1984:87), 40 km (25 miles) northeast of the project area. Human groups of this time "may have wandered from place to place; others may have followed an annual round, moving systematically from one place to the next in order to take advantage of seasonal resources" (Moratto 1984:78). These groups may have created more permanent settlements at locations that were particularly attractive, such as near large marshes or estuaries. If Paleoindian materials tend to be located in basins that supported wetlands, the subsequent erosion and/or filling of these basins with sediment may have been destroyed or buried sites of this period.

Evidence of Lower Archaic Period occupation (8,000-4,500 B.P.) has been identified at many locations in California, including some sites in the central part of the state. Artifacts from this period suggest a general transition from hunting to the collection and processing of plant foods as indicated by the occurrence of sites that yield few projectile points, but many millingstones (Wallace 1978). Millingstone sites have been found along the southern and central Pacific coast, and at inland locations in the Coast Ranges and Central Valley (Fitzgerald 1993; Jones 1991). The use of inland site locations suggests that wetland environments used by previous peoples may have proved inadequate to support the increasing number and stability of human settlements that appear during this period (Jones 1991). The discovery of millingstone period sites in various upland locations suggests that "additional settlements of this kind lie deeply buried beneath river-deposits alluvium" (Wallace 1978:29).

Human occupation during the Middle Archaic Period (4,500-2,500 B.P.) in Central California is most clearly indicated by the Windmiller Pattern, also known as the Early Horizon (Beardsley 1954; Heizer 1949). The Windmiller Pattern appears to represent a highly developed cultural group that was preadapted to riverine and wetland environments when they arrived in the region (Moratto 1984:207). Windmiller sites reportedly include numerous baked clay balls, many projectile points, marine shell ornaments and beads, cylindrical charmstones, few bone tools, very little milling equipment, non-midden cemeteries, and ventral-extended burials oriented toward the west (Bennyhoff 1994; Moratto 1984). The high proportion of projectile points in comparison to milling tools at these sites indicates an apparent emphasis on hunting over plant processing.

Typical Windmiller Pattern sites are generally located in the Central Valley near the margins of the present delta, such as those found directly east of

the project area near Stockton. Windmiller groups may have moved seasonally, occupying the Central Valley during the winter and the nearby foothills during the summer (Moratto 1984:206). Many of the Windmiller sites are located on natural levees that parallel stream channels or on clay or sand knolls that are elevated above the surrounding delta plain. Some of these sites "are almost completely buried by river sediments" (Beardsley 1954:64), and are more than 100 cm below mean sea level at their base (Heizer 1949:5). It appears that the knolls and levees represent older, stable landforms that were originally occupied by Windmiller groups before the delta plain had fully formed, whether due to late Holocene subsidence and/or continued sea level rise.

It has become increasingly evident that a cultural group represented by the Berkeley Pattern, occupied the San Francisco Bay Area at the same time that Windmiller Pattern occupied the Central Valley (Gerow and Force 1968; Moratto 1984; Fredrickson 1994b). Human occupation of the region during the Upper Archaic Period (2,500-1,000 B.P.) is most clearly represented by the Berkeley Pattern, also referred to as the Middle Horizon. The Berkeley Pattern is characterized by thick shell middens, many bone tools, flexed burials with variable orientations, and a high proportion of mortar and pestle milling tools as compared to projectile points. Although many Berkeley Pattern sites have been identified near the shores of San Francisco Bay, they have also been found at more inland locations such as in the San Ramon and Livermore Valleys. Sites belonging to the Berkeley Pattern have been found beneath 100 cm or more of sterile alluvial sediments at many locations in the region.

The Lower Emergent Period (1,000-500 B.P.) is marked by a significant social, economic, and technological change that spread rapidly through Central California (Fredrickson 1994a). These changes are thought to have occurred in response to southward expansion into the region of a new population (the

ancestral Patwin) and because of improving environmental conditions (Bennyhoff 1994; Moratto 1984). "Phase 1" of the Augustine Pattern represents the merging of earlier Berkeley Pattern traits with the innovations of new local populations during this period. The sites of the Augustine Pattern contain small arrowpoints, well-shaped mortars and pestles, bone tools, fishing implements, charmstones, spire-lopped olivella beads, grave pit burning, and flexed and cremated burials. These materials reflect the adoption of bow and arrow technology, an emphasis on acorn processing and fishing, and an increasing reliance on trade goods and exchange networks. Although the number of individual settlements appears to increase during this period, they seem to become smaller or more aggregated in terms of their physical size. Settlements belonging to the Augustine Pattern are expected to occur at or near the present land surface located along present margins of the bay-delta and the confluences of perennial stream and river channels, particularly in favorable fishing localities.

The innovative trends of the previous period became more regularized during the Upper Emergent Period (500-200 B.P.), as represented by Phase 2 of the Augustine Pattern. Continued population growth appears to have led to greater distinctions of wealth, status, and power among individuals and different cultural groups. Increased social stratification lead to the development of craft specialization and more complex exchange networks to support the cultural infrastructure. Small groups may have been forced to settle in less productive areas of the region as other groups grew larger and more powerful. Larger Phase 2 settlements occupy many of the same locations as the previous phase, however, smaller Phase 2 settlements may be expected to occupy more inland locations. Most settlements of this type would be expected to occur at or near the present land surface.

During the Historic Period (<200 B.P.), the Los Vaqueros Project area was located near the interface of four ethnolinguistic groups: the Bay Miwok, the Northern Valley Yokuts, the Ohlone, and the Plains Miwok. Despite the lack of direct ethnographic accounts, each of these groups is believed to have utilized the project area to a greater or lesser degree (Bennyhoff 1994). Historical research suggests that the Volvon triblet of the Bay Miwok inhabited a village in the area of Marsh Creek and/or Round Valley at the time the area was purchased by John Marsh in 1838 (Milliken 1986:29).

Landscape Evolution and the Archaeological Record

Archaeologists working in Central California have long known that sites are often buried by sediments deposited by natural geological processes (Heizer 1952:9; Moratto 1984:214). Although it is commonly understood that "older sites are harder to find and are more apt to be buried or destroyed by erosional processes," it is rarely acknowledged that "the relative scarcity of older sites is therefore a reflection of the present state of our archaeological knowledge rather than a true picture of cultural history" (Meighan 1965:709). To date, no archaeological studies have been conducted that have systematically examined the influence of regional geological processes on the burial of archaeological materials in Central California. Instead, buried archaeological materials are generally discovered accidentally after they are exposed by natural erosion or mechanical excavations (Cook and Elsasser 1956:32; Heizer 1950:8). The lack of systematic studies is an ongoing problem for investigators concerned with how and where to locate buried archaeological materials, and for studies that attempt to evaluate the significance of these resources in view of the nature and completeness of the region's archaeological record.

A few archaeological studies conducted in the Northern Coast Ranges of California have examined certain relationships between geological processes and archaeological site formation (Meyer 1993, 1994, 1995; Rosenthal, Meyer, and White 1995; Waters 1995; Meyer and White 1995). Archaeological materials were found to be associated with a buried paleosol that was capped by 2.5 m of sterile alluvium at a site in Santa Rosa, California (Meyer 1993). Extensive study of the Anderson Flat area near Lower Lake, demonstrated that the distribution and preservation of earlier archaeological materials were directly related to the distribution and preservation of an early to middle Holocene paleosol, partially buried by late Holocene alluvium (Meyer 1995; Meyer and White 1995; Waters 1995). Studies along a portion of Cache Creek in Lake County indicate that the range and relative age of human occupation are closely associated with a sequence of abandoned stream terraces (Meyer 1994). Investigations along a minor tributary of Putah Creek near Middletown, California found that archaeological materials were deposited over a period of about 7,000 years on a stream terrace that remained stable throughout the Holocene (Rosenthal, Meyer, and White 1995). Although each of these studies found a strong correlation between the relative stability and instability of certain landforms and the age and distribution of archaeological materials, the regional significance of these findings was not evaluated.

The archaeological implications of world-wide sea level change have been recognized in Central California by Atwater (1979), Bickel (1978), Helley, Adam and Burke (1972), and Helley et al. (1979). The apparent lack of archaeological sites in the Bay Area greater than 5,000 years old, have lead investigators to speculate that if there were older sites, "they have already been destroyed, or they lie buried beneath the water and mud of San Francisco Bay" (Helley, Adam, and Burke 1972:29). The reason for this is explained as follows:

> Given the rapidity of changes in sea levels and shorelines 5,000-10,000 years ago, sites of habitation located at that time along the shores of estuaries must now lie beneath mud and tidal water. Sites younger than 5,000 years, alternatively, postdate rapid submergence and would therefore more likely escape total inundation [Atwater 1979:40].

This theory is confirmed in part by geological studies that found that alluvial deposits around the bay contain a variety of cultural and non-cultural materials that are 5,000 years of age or less (Helley at al. 1979:29). It would appear that the distribution of human habitation sites in the San Francisco Bay Area was significantly influenced by differential submergence rates before and after 5,000 B.P. (Atwater 1979).

The consequences of these factors for the archaeological record in the San Francisco Bay Area have been reviewed by Bickel (1978). Some of the earliest evidence of human occupation in the Bay Area is isolated skeletal remains with radiocarbon ages that range from about 4300 B.P. to 5100 B.P. Most of the burials were discovered at inland locations at depths of 2 m to 6 m below the surface. However, a burial discovered near the present shoreline was found at a depth of 16 meters below the historic ground surface, or 8 meters below mean sea level (Henn, Jackson, and Schlocker 1972). At another location near the present shoreline, archaeological materials as little as 3,000 years old are buried 1.8 m to 2.7 m below the ground surface (Gerow and Force 1968). Based on the age and distribution of sites older than 5,000 B.P., Bickel concluded that evidence for early occupation of the area is lacking "at least partly because it is buried, or perhaps submerged under water" (Bickel 1978:15). In addition, "alluvial deposition may partly account for the relative paucity of evidence of early occupation" in areas located some distance from the shoreline (Bickel 1978:15).

Buried Sites

A few studies have considered the influence of geological processes on the burial of single sites or limited areas in Central California (Fredrickson 1966, 1980; Banks et al. 1984). Buried archaeological sites have been discovered in many parts of the region, particularly in the valleys of interior Contra Costa and Alameda counties. In an archaeological overview of the Walnut Creek area, Fredrickson noted that "a significant number of archaeological sites recorded within the present study area apparently did not contain identifiable surface markings but were found buried beneath non-archaeological alluvial soils" (1980:5). Fredrickson pointed out that some type of subsurface exploration was necessary to locate and identify these buried sites.

As part of a review of archaeological sites located in the Walnut Creek drainage, investigators evaluated the estimated age, depth, and distribution of 22 archaeological sites (Banks et al. 1984). More than one-half (13) of these sites were buried or found to contain a buried cultural deposit overlain by sterile alluvium. Most of the buried sites had been discovered accidentally during earth moving activity, however, at least one site (CA-CCO-431) was identified by a subsurface archaeological testing program. Sites in the Walnut Creek drainage were buried by sterile alluvium that varied from as little as 15-30 cm at CA-CCO-308 to as much as 255-395 cm at CA-CCO-431 in thickness.

Two sites with buried components (CA-CCO-30 and CA-CCO-308) were identified on the west side of San Ramon Creek. The lower component (B) at CA-CCO-30 was buried 167-198 cm below the surface and separated from the upper component (A) by about 90 cm of sterile alluvium (Fredrickson 1968:139). At site CA-CCO-308, three distinct cultural deposits were identified, each separated by a layer sterile alluvium. The deepest buried component ("c") was about 180-229 cm below the surface, and was estimated to be 4,000 to 3,000

years old on the basis of radiocarbon determinations. Not only was each of the cultural deposits at CCO-308 associated with a "buried A horizon," but an even deeper A horizon lacking cultural materials was identified at a depth of approximately 286-305 cm below the surface (Fredrickson 1966:9 and Figure 1).

The buried cultural materials at site CA-CCO-431 were found to be associated with a "buried surface" that ranged from 255 cm to 395 in depth, comparable to the "c" component at CCO-308 (Banks et al. 1984:8.24). A radiocarbon age of 2870 +/- 120 B.P. obtained from an elk bone recovered from the cultural deposit is with the range of ages obtained from CCO-308. In addition to the buried cultural surface, CA-CCO-431 also produced evidence of two other buried surfaces lacking cultural materials -- one stratigraphically above and one below the cultural deposit.

A review of 22 archaeological sites identified in the Walnut Creek drainage indicates that 13 (59%) were partially or completely buried by sterile alluvium. The average depth of cultural deposits at these sites that range from 111 cm to 171 cm below the surface, with an overall average of 141 cm below the surface as summarized in Table 1. Because the majority of these sites were found to be buried by sterile alluvium, the depth of the cultural deposits may be interpreted as representing the depth of a buried land surface (paleosol). A comparison of the depths of the three buried paleosols observed at CCO-308 (excluding the A component) and CCO-431 indicates that the upper paleosol averages 113 cm, the middle paleosol averages 257 cm, and the lower paleosol averages 410 cm. It is important to note that no archaeological materials were identified with the lower paleosols at these sites. The correspondence between these depths and the stratigraphic position of the buried paleosols suggests that the Walnut Creek drainage contains one or

more relatively continuous Holocene age land surfaces that are now buried by alluvium.

TABLE 1. Average Depth of Buried Cultural Deposits and Paleosols (+). Adapted from Banks et al. (1984).

Site CA-	Min. Depth	Max. Depth	Ave. Depth
CCO-308A+	15 cm	30 cm	22 cm
CCO-4	70 cm	90 cm	80 cm
CCO-225	90 cm	90 cm	90 cm
CCO-308B+	57 cm	152 cm	104 cm
CCO-137	111 cm	121 cm	116 cm
ALA-394	122 cm	122 cm	122 cm
ALA-413	45 cm	210 cm	127 cm
CCO-23	0 cm	260 cm	130 cm
CCO-133	158 cm	178 cm	168 cm
CCO-305	180 cm	180 cm	180 cm
CCO-30	167 cm	198 cm	182 cm
CCO-308C+	180 cm	229 cm	204 cm
CCO-431 +	255 cm	365 cm	310 cm
Total Ave.	111 cm	171 cm	141 cm

NOTE: CCO-308 depths corrected for 2:1 slope in Figure 1 of Fredrickson (1966: 192).

The occurrence of three buried surfaces at two separate locations (CCO-308 and CCO-431) in the same drainage prompted investigators to speculate that the surfaces,

> ...may be regional in scope and, as such, could represent three periods of stability, during which an A horizon was formed, each of which was followed by three periods of more intense deposition. The transition between stable and depositional phases appears to reflect major changes in climate [Banks et al. 1984:8.28].

Based on archaeological and geological evidence, periods of intense alluvial deposition were hypothesized to have occurred at 2800-2700 B.P., 1900-1500 B.P., and 700-600 B.P. The periods of deposition were roughly correlated with periods of heavy rainfall caused by climatic changes during the late Holocene, such as those corresponding to the Recess Peaks and Matthes glacial advances in the Sierra Nevada (Curry 1968, 1969). It was observed that all of the buried sites were older than the last period of deposition, while all but two of

the surface sites were younger than the last period of deposition around 650 years ago. The investigators suggest that apparent breaks in cultural patterns coincide with significant changes in the climatic and depositional history of the region. They concluded that:

> If this is true, the same type of correlation should be found in other areas of California. Thus, a climatic chronology must be part of, and correlate with, any cultural sequences proposed for Central California. [Banks et al. 1984:3.22].

Previous Los Vaqueros Studies

Numerous cultural resources management surveys, studies, and inventories have been conducted during various phases of the Los Vaqueros Project. The results of the major studies are summarized by Bramlette et al. (1991a) and will not be reviewed here. At least 20,000 acres in and around the Kellogg Creek drainage have been systematically surveyed for archaeological resources. The proposed Pipeline Route and several alternative routes were surveyed and/or studied by one or more of the following investigations: Bramlette et al. (1988, 1991b); Eidsness (1986); Fredrickson (1982); Jensen & Associates (1986); Jones & Stokes Associates, Inc. and Woodward-Clyde Consultants (1992). Despite many surface surveys of the area, very few prehistoric sites were identified along the watercourses in the valleys of the area, where higher site densities were expected (Bramlette et al. 1991b:14).

The low number of sites identified in the valleys is more striking when compared to the number of sites identified on the hillslopes. Of the 24 prehistoric sites identified in the Los Vaqueros study area, 20 (83%) of were located in the hillslopes and only four were located in the valleys. Although the Pipeline Route intersects four substantial drainage basins, only three sites were identified near the route: one historic (CA-CCO-446H), one prehistoric (CA-

CCO-637), and one that is historic and prehistoric (CA-CCO-447/H). As a whole, the majority of the valley sites date to the Historic Period, while one of the few recorded prehistoric sites (CA-CCO-458/H) appears to have been occupied during the Upper Emergent Period or post 900 B.P. (Fredrickson 1982:130). Although site CCO-637 was identified at the surface, it was determined that the archaeological materials had been brought to the surface by trenching for a gas pipeline that crossed the site.

The initial Los Vaqueros predictive models posited that human use of the Los Vaqueros area began some 3000 to 3500 B.P., with the most intensive use occurring 2000 to 1500 B.P. (Bramlette et al. 1988: 2). In contrast, it was determined that year-round residential use of the area did not begin until the Emergent Period based on an analysis of obsidian hydration data and landforms (Bramlette 1989:123). Of the 112 obsidian hydration rim values obtained for the study, 90% range from 1.0 to 3.0 microns (Napa Valley), while the remaining 10% range from 4.0 to 6.5 microns (Napa Valley). Despite the larger rim values that suggest some human use of the area as much as 6000 B.P., Bramlette (1989) argued that the low number of larger values indicates the project area was occupied only sporadically prior to 1000 B.P. While the apparent lack of older archaeological materials appeared to document exclusive occupation during the Emergent Period, Bramlette did not interpret these results in view of the extensive regional evidence that indicates geological processes have destroyed or buried the evidence of earlier human occupations in Contra Costa County alluvial basins.

<u>Recent Los Vaqueros Studies</u>

Recent archaeological and geoarchaeological investigations in the Los Vaqueros Reservoir area indicate that significant deposits of archaeological

materials can occur in association with two buried paleosols in the valley basins (Meyer 1995, 1996; Meyer and Rosenthal 1996). A previously unknown buried archaeological site (CA-CCO-696) was discovered during subsurface test excavations in the Kellogg Creek floodplain near the proposed Dam footprint. The upper of two buried deposits at the site were found to contain over 160 human graves, substantial quantities of flaked stone and faunal debris, and more than 20 intact residential features directly associated with a paleosol (designated the Vaqueros Paleosol) buried by 60-140 cm of sterile alluvium (Figure 4). Preliminary identification and cross-dating of the archaeological materials indicates an initial Upper Archaic Period occupation that gave way to Emergent Period occupation later in time. Initial radiocarbon analysis indicates that the Vaqueros Paleosol was occupied between 3000 B.P. and 700 B.P., before being buried by sterile alluvium around 500 B.P. The Vaqueros Paleosol appears to have been available for human occupation for at least 2,300 years.

Further geoarchaeological testing revealed the presence of archaeological materials at a depth of 320-410 cm below the surface in association with a deeply buried paleosol (designated the Kellogg Paleosol) found underlying the Vaqueros Paleosol (Figure 4). Archaeological materials recovered from the lower deposit include flaked stone, core tools, handstones, millingslabs, one human burial, and a wide-stemmed projectile point with an obsidian hydration rim value of 6.9 microns (Napa Valley). The artifact assemblage appears to be typical of the Western Pluvial Lake Tradition (Lower Archaic Period). Initial radiocarbon analysis from cultural charcoal indicates that the Kellogg Paleosol was occupied between 7400 cal B.P. and 9800 cal B.P., before being buried by sterile alluvium around 7000 cal B.P. The Kellogg

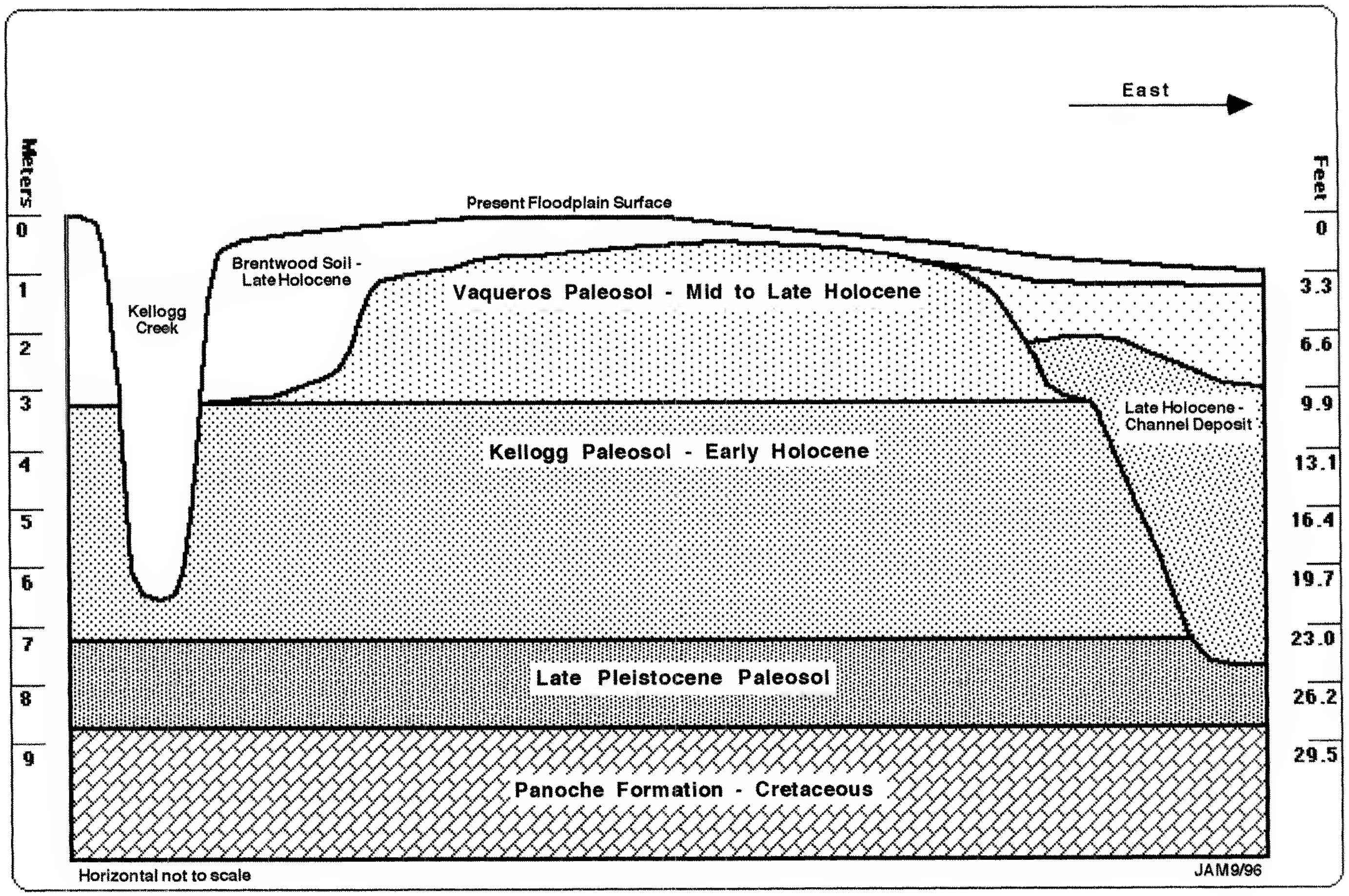


FIGURE 4. LANDSCAPE-SEDIMENT ASSEMBLAGE AT CA-CCO-696

Paleosol appears to have been available for human occupation throughout the early Holocene.

The recent findings from the Los Vaqueros Reservoir area demonstrate: (1) that prehistoric people occupied the area earlier than previously estimated; (2) that two separate buried paleosols represent former land surfaces that were occupied by prehistoric people; (3) that archaeological materials more than 700 years old are buried by sterile alluvium in the Kellogg Creek valley; and (4) that geological processes have profoundly influenced the visibility and structure of the archaeological record in the area. Given the findings of previous studies, a geoarchaeological approach was adopted in order to evaluate the potential for buried archaeological materials along the Pipeline Route.

CHAPTER 3

GEOARCHAEOLOGICAL APPROACH

Background

The fields of archaeology and geology have a history of interdisciplinary cooperation that spans more than a century in North America (Gifford and Rapp 1985; Renfrew 1976). The traditional role of geology in archaeology has been to document stratigraphy and establish the apparent age of artifacts, such as the discovery of fluted projectile points with extinct bison in a buried soil near Folsom, New Mexico in 1927 (Wormington 1957). Although many advances were made by these early studies, they were often conducted without a theoretical framework, and lacked uniform methods and reporting standards (Lasca and Donahue 1990). While both disciplines continue to share stratigraphy, geochronology, and paleoenvironmental reconstruction as common research interests, they tend to operate at different spatial and temporal scales of inquiry (Stein 1993).

The emergence of geoarchaeology as a subdisclipline of archaeology during the 1970s and 1980s is an outgrowth of the federal legislation that fostered the growth of the cultural resources management industry (Bettis 1985, 1992a). As more of the landscape was investigated by cultural resources management studies, it became evident that significant portions of the archaeological record were buried and could not be detected by conventional methods. As awareness of this problem increased, the economic advantage of performing geoarchaeological investigations that estimate the potential for buried archaeological resources became apparent to some federal agencies. Because government agencies and private industries have sought to find more effective and efficient ways to manage archaeological resources, the demand

for trained archaeological geologists and geoarchaeologists has increased (Thorson and Holliday 1990; Blackwell 1993).

Archaeological geology is defined as "the application of geological principals and techniques to the solution of archaeological problems" (Gifford and Rapp 1985:19). The Geological Society of America established an Archaeological Geology Division in 1977 that "provides a formal recognition of the mutual contribution of geologists and archaeologists to an understanding of the geological problems of the archaeological past" (Hassan 1979:267). However, standard geological inquiry is often inadequate for solving archaeological problems at the level of detail sought by archaeologists (Gladfelter 1981:345). For this reason, "geological investigations should be integrated with archaeological work to be truly geoarchaeological" (Hassan 1979:269).

In 1973, the term geoarchaeology was first used by Karl Butzer who later defined it as "archaeological research using the methods and concepts of earth sciences" (Butzer 1982:35). Gladfelter (1977:519) further defines geoarchaeology as: "the contribution of the earth sciences, particularly geomorphology and sedimentary petrography, to the interpretation and environmental reconstruction of archaeological contexts." Thorson and Holliday (1990:20) have discussed the significance of these alternative terms and concluded that geoarchaeology is more inclusive than archaeological geology, and is therefore the preferred term because it "connotes both the historic affiliation and mutual dependency between the disciplines."

Theoretical Overview

Geological and archaeological studies are unified by the principals of uniformitarianism and stratigraphic succession. Uniformitarianism is the view

that processes operating at the present have operated the same way in the past to produce similar results even though the processes may not have operated at the same rate or intensity. The uniformitarian principal is a central part of geoarchaeological reasoning, providing a basis for understanding the nature of past processes. The principal of superposition is derived from the observed stratigraphy of geologic deposits in which the upper are considered to be younger than the lower, unless some type of inversion can be demonstrated. For geoarchaeology, the study of stratigraphy is fundamental for establishing the spatial and temporal relationships between soils and sediments (Waters 1992).

In addition to the uniformitarian and superposition principle, certain concepts developed in the fields of geography, geomorphology, and pedology are often applied in geoarchaeological studies. The result is the formulation of a landscape approach to archaeology that incorporates many aspects of human ecology, landscape evolution, and soil formation. A landscape approach is defined "as the archaeological investigation of past land use by means of a landscape perspective, combined with the conscious incorporation of regional geomorphology, actualistic studies (taphonomy, formation processes, ethnoarchaeology) and marked by ongoing reevaluation and innovation of concepts, methods, and theory" (Rossignol 1992:4). The methods and application of a landscape approach are linked to general theory by uniformitarian assumptions and specific questions regarding observed changes in human land use and social organization in the past. The ultimate goal of a landscape approach is to understand human social and economic change within the framework of an inclusive environmental and evolutionary context (Rossignol 1992:14).

Landforms and geological processes are significant factors in regulating the structure and function of eco-systems, which control the flow of materials and energy across a landscape (Stafford 1995:76). The distribution, organization, and interrelationships of people are likewise configured by these factors. At any one time, the landscape is composed of a mosaic of different deposits, soils, and landforms of various ages. This physical platform on which people interacted with their environment is the geomorphic landscape (Waters 1992:88). Evidence of past human alteration and/or occupation of a landscape is subject to the same processes that affect the preservation, distribution, and visibility of the non-cultural deposits (Bettis 1992b:119). The depositional history and subsequent evolution of a landscape ultimately determine whether archaeological materials will be preserved, destroyed, or redeposited (Kuehn 1993; Waters 1992).

Applied Concepts

The study of geoarchaeology is dependent on a clear understanding of the interaction between people and the landscape (Butzer 1982; Davidson and Shackley 1976; Holliday 1992; Rossignol and Wandsnider 1992; Stein and Farrand 1985; and Waters 1992). On the landscape side of the equation, this requires the geoarchaeologists to identify and evaluate some of the processes that control the structure of geological, pedological, and geomorphological systems. Foremost among these are stratigraphy, soil formation, and landscape evolution. Together these concepts provide a basis for evaluating the age and distribution of deposits, soils, and landforms in terms of past human occupation.

There is a fundamental distinction between soil and sediments, while sediments are particles that have been transported and deposited by geological processes, soil is formed by the in-place alteration of rock and sediments. The

process of soil formation involves the addition, transformation, transfer, and removal of materials and chemicals in the soil as determined by the factors of climate, organisms, relief, parent material, and time (Holliday 1990). The combined effect of these factors at or near the surface results in the formation of subsurface horizons that become more distinct or well-developed. Weakly developed soil has little or no horizon development that tends to be associated with young and/or unstable landforms. Well-developed soils have distinct horizons and tend to be associated with older, more stable landscapes. When erosion removes the surface of a landform, the process of soil formation is resumed on the newly exposed surface. In the case where the surface of a landform is buried by a thick deposit of sediment, soil formation is stopped on the buried land surface, and resumed on the newly deposited surface.

A soil that formed on a landscape in the past, but is not actively forming at the present, is known as a paleosol (Retallack 1988; Waters 1992; Yaalon 1971). The recognition of paleosols is crucial for geoarchaeological studies because they represent former land surfaces that were stable and potentially available for human occupation. Buried paleosols reflect the conditions of soil formation that occurred at or near the surface during a prolonged period of landform stability (Birkeland, Machette, and Haller 1991). A paleosol may represent hundreds or thousands of years of non-deposition and soil formation depending on the length of the stable period. Once buried, paleosols represent unconformities with overlying deposits that can be used as stratigraphic markers (Holliday 1990). There are a variety of published works that provide more in-depth discussion of the use and interpretation of soils, sediments, and paleosols in archaeology (Birkeland 1984; Holliday 1990, 1993; Ferring 1992; and Waters 1992).

Predicting Site Locations

Archaeologists have long depended on intuitive techniques that are largely subjective and inexplicit for predicting site locations (Clarke 1977:5; Altschul 1988:63). As a result, there is a lack of explicit and testable models that can accurately predict the location of archaeological sites, especially those sites that are buried. In an attempt to remedy this problem, archaeologists have developed two basic types of models for predicting site locations.

A predictive locational model is: "a simplified set of testable hypotheses, based either on behavioral assumption or on empirical correlations, which at a minimum attempts to predict the loci of past human activities resulting in the deposition of artifacts or alteration of the landscape" [Kohler 1988:33]. Most locational models depend on causal relationships between culture and environment that assume a cultural ecological approach that is essentially a form of environmental determinism (Kohler 1988:19). This type of approach often uses an inductive locational model based on the empirical correlation of quantifiable variables between known site locations and environmental conditions. While predictive locational models can be useful in meeting cultural resource management needs (Nickens and Chandler 1987), critics argue that the approach is atheoretical and presupposes direct environmental causation (Ebert and Kohler 1988; Rogge and Lincoln 1987).

As an alternative to the empirical predictive model, archaeologists have attempted to develop explanatory models of human decision making and locational behavior (Jochim 1976). The goal of the explanatory approach is the development of a deductive locational model based on some explanation or theory about human behavior (Kohler and Parker 1986). Locational behavior is seen as the response of human groups to the presence or absence of important resources, the relative attractiveness of resources, and the physical distance

between important resources (Bettinger 1980). Site location is then viewed as a combination of human needs and choices that are for the most part satisfied by a particular environmental setting. In short, human groups will tend to use and occupy those portions of a given landscape that are reasonably close to a variety of important resources. Predictive locational models that use this approach have been developed by Bettinger (1980), Helmer (1992), and Jochim (1976).

Critics point out that explanatory models are not only difficult to construct, but that the ability of the approach to predict site locations are completely dependent on its theoretical assumptions, which may or may not be correct (Kohler and Parker 1986). It is also difficult to integrate non-economic and/or non-optimal aspects of human behavior that influence locational decision making into any type of predictive modeling approach. An additional problem stems from the belief that because depositional and postdepositional processes are unpredictable, they should not be considered in the development of predictive locational models. Instead, deposition is not a random but a highly regularized natural process controlled by specific conditions in the physical environment that are predictable once they are determined. Therefore, the distribution and impact of depositional processes "must be understood before predictive modeling can become an operational tool for cultural resources management" (Ebert and Kohler 1988:126)

This review of predictive locational models suggests that there is a need for: (1) better developed theoretical models of prehistoric human behavior and settlement patterns; (2) additional data and methods for analyzing the spatial relationships of archaeological materials across the landscape; and (3) more investigations that consider the potential influence of geological processes on

the differential preservation and/or burial of landscapes that were used by people in the past. The current study focuses on the latter factor.

Locating Buried Sites

Archaeologists have traditionally relied on the use of surface surveys as a method of searching an area for archaeological site locations (Dunnel and Dancey 1983). With the increasing regional orientation of archaeological research, the survey is viewed as a fundamental sampling method that permits the discovery of unknown sites, while providing data for assessing site location and discovery probability (McManamon 1984; Nance 1983). Different environmental conditions often demand the application of appropriate survey techniques and sampling strategies to increase discovery probabilities (Schiffer, Sullivan, and Klinger 1978:8). If it is recognized that buried sites "are probably always underrepresented in survey samples" (Nance 1983:349), the difficulty of locating buried sites can be confronted as a sampling problem as part of the survey design (McManamon 1984). The design of a survey should not only consider the possibility of buried sites, but also address the probability of discovering buried sites in different parts of the study area.

A buried site refers to any relatively intact archaeological material that is concealed from view by a distinct and/or significant deposit of natural sediments. The probability that a buried site will be discovered depends on two important factors -- visibility and obtrusiveness. Visibility is "the extent to which a site has been buried or covered by soil aggradation and vegetation since its last occupation" (McManamon 1984: 224). The obtrusiveness of a site determines "the probability that particular archaeological materials can be discovered by a specific technique" (Schiffer, Sullivan, and Klinger 1978:6). Discovery probability is "the likelihood that cultural remains of interest will be

detected within a sampling domain or sampling unit using a specified sampling procedure, given a certain level of sampling effort" (Nance 1983:292). Because buried sites generally lack visible and/or obtrusive features that would otherwise indicate their presence to an observer in the field, the use of pedestrian survey methods is often inefficient or completely ineffective for locating buried archaeological sites (Bettis 1992b:120). Surveys that are designed to locate and estimate the potential of buried sites must rely on other methods and techniques to avoid the sampling biases introduced by traditional surface surveys.

A wide variety of methods, techniques, and sampling strategies have been proposed for locating buried sites, though not all of them are equally appropriate or effective in all situations (McManamon 1984:224). Archaeologists have used shovel tests, hand and power augers, tractor mounted backhoes, and/or mechanical coring devices to test for buried sites. The selection of an effective technique is dependent on expectations regarding the probable nature of the archaeological materials and the type of deposits that must be searched. Various hand augers and coring tools can be used to test sites that are 20--100 cm in depth. However, for sites that are buried by more than 100 cm of non-cultural sediments, it is often necessary to use a backhoe or other powered equipment (Schiffer, Sullivan, and Klinger 1978). The excavation of subsurface test trenches using a backhoe is common practice in geoarchaeological studies because the resulting trenches are an effective source of geomorphological information, and because they are more efficient than manual excavations in terms of time and cost (Association of Iowa Archaeologists 1992).

Subsurface Surveys

There are many studies that illustrate the design and application of a subsurface survey for the purpose of locating and predicting the contexts of buried sites (Artz 1985, 1995; Bettis 1992b; Bettis and Benn 1984; Bettis and Hajic 1995; Bettis and Littke 1987; Gardner and Donahue 1985; Hajic 1985; Mandel 1992, 1995; Mandel et al. 1991; Stafford 1995; Stafford and Hajic 1992; Waters 1988). Each of these studies was designed to evaluate the relationships between landscapes and the location of archaeological sites, using a similar combination of research methods and field techniques for testing subsurface deposits. The primary purpose of this type of study is to develop models for estimating the potential of buried sites, and not to locate every site that may be buried in the study area. This is generally done by establishing the temporal relationship of deposits and landforms on the basis of stratigraphy and the degree of soil formation. Radiocarbon dating is often critical for resolving the absolute age of the deposits, especially when archaeological materials fail to provide useful chronological controls (Bettis and Benn 1984). Deposits and landforms that are genetically and temporally related are grouped into landform-sediment assemblages (Bettis 1992b:133). The ability of the model to locate buried sites depends on the age and distribution of those landform-sediment assemblages that can be adequately tested for evidence of past human occupation.

Some of the important findings made by previous geoarchaeological studies are as follows: (1) "the spatial distribution of artifacts across the landscape is a function of the scale of landforms and the arrangement of landscape elements that served as stopping points (places) on those landforms" (Stafford and Hajic 1992:158); (2) " the buried archaeological record is generally subject to many of the same processes that affect the modern

surface record," such as the long-term accumulation of cultural materials on a single geomorphic surface (Stafford 1995); (3) "the landscape is dynamic and can change in a relatively short period of time" (Bettis and Benn 1984:223); (4) the nature and distribution of subsurface deposits are often unrelated to deposits at the surface (Hajic 1985:135); (5) certain landforms are either too young or too old to contain buried sites (Gardner and Donahue 1985; Mandel 1995); (6) erosion has created gaps in the archaeological record (Kuehn 1993; Mandel 1992; Waters 1988;) and (7) the age and distribution of landform-sediment assemblages may differ significantly from one area to the next (Artz 1985; Mandel 1992, 1995). Many of these findings are applicable for archaeological and geoarchaeological studies in the Los Vaqueros area and other parts of California.

CHAPTER 4

SURVEY DESIGN AND METHODOLOGY

General Approach

The initial phase of this geoarchaeological survey involved a review and assessment of the available information regarding the archaeology and geology of the study area. This was followed by preliminary field checks to confirm the accuracy of the information and to examine natural cutbanks and excavated exposures for buried paleosols and archaeological materials. Backhoe trenching was selected as an appropriate technique for subsurface testing because it provides geomorphological information and the opportunity for site discovery. Expectations regarding site and landform relationships were tested in the field and the initial findings are then used to further develop and refine field strategies. Finally, certain landform contexts were targeted for subsurface survey to determine the presence or absence of buried archaeological materials and answer related research questions.

Survey Design

The various types of deposits expected in the project area were identified (Appendix B). The project area was divided into landscape segments on the basis of soil type, topography, geology, and geographic location as shown in Figure 5. The landscape segments were then separated into two basic types: (1) hillslopes -- moderately to steeply sloping hills and footslopes formed by erosion and hillslope processes; and (2) valleys -- gently sloping alluvial fans and floodplains formed by depositional processes as depicted in Figure 6. The length of the landscape segments is summarized in Table 2. Using these distinctions, the valley segments were targeted for subsurface survey because

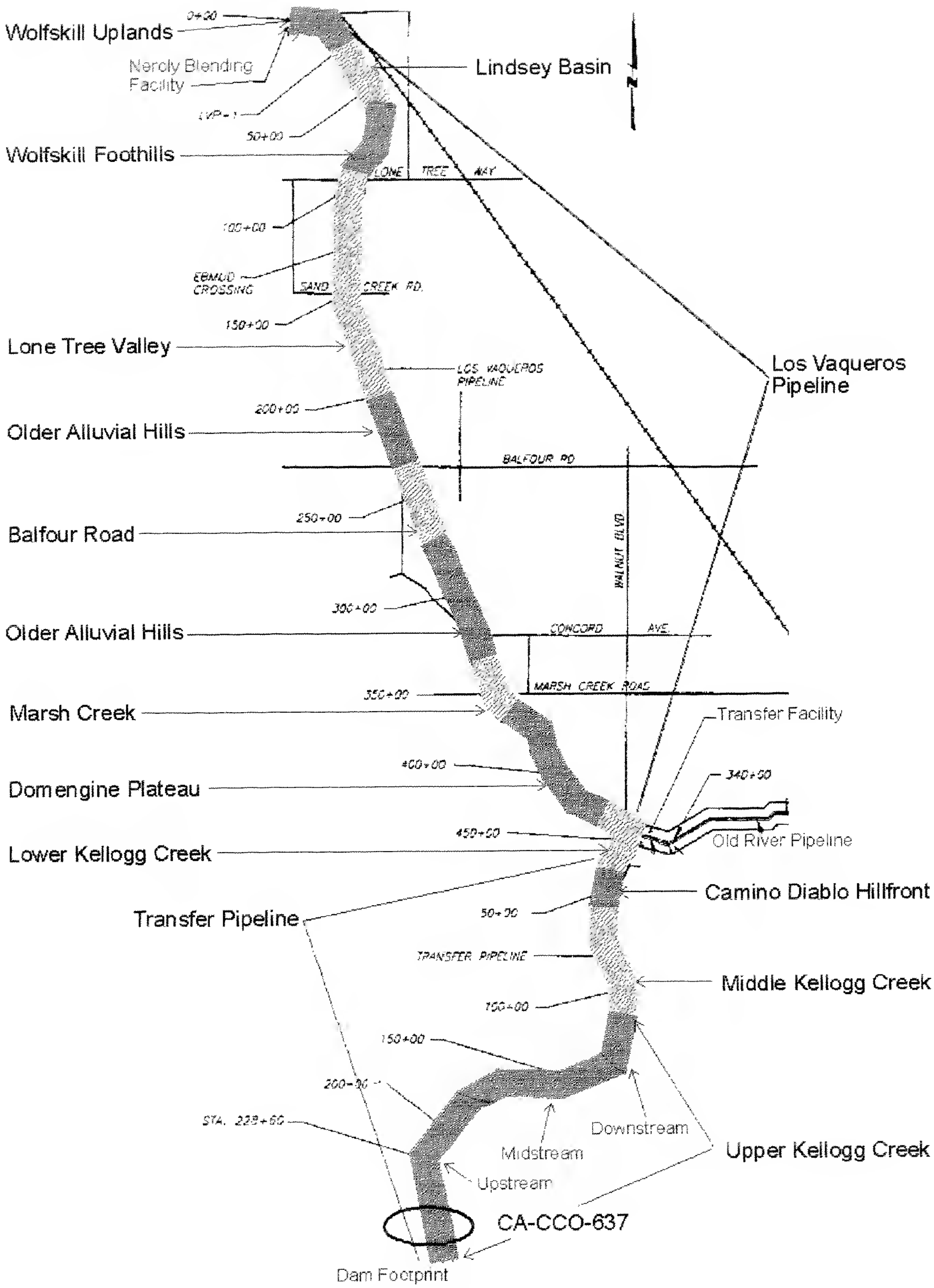


FIGURE 5. LOCATION OF LANDSCAPE SEGMENTS ALONG THE PIPELINE ROUTE

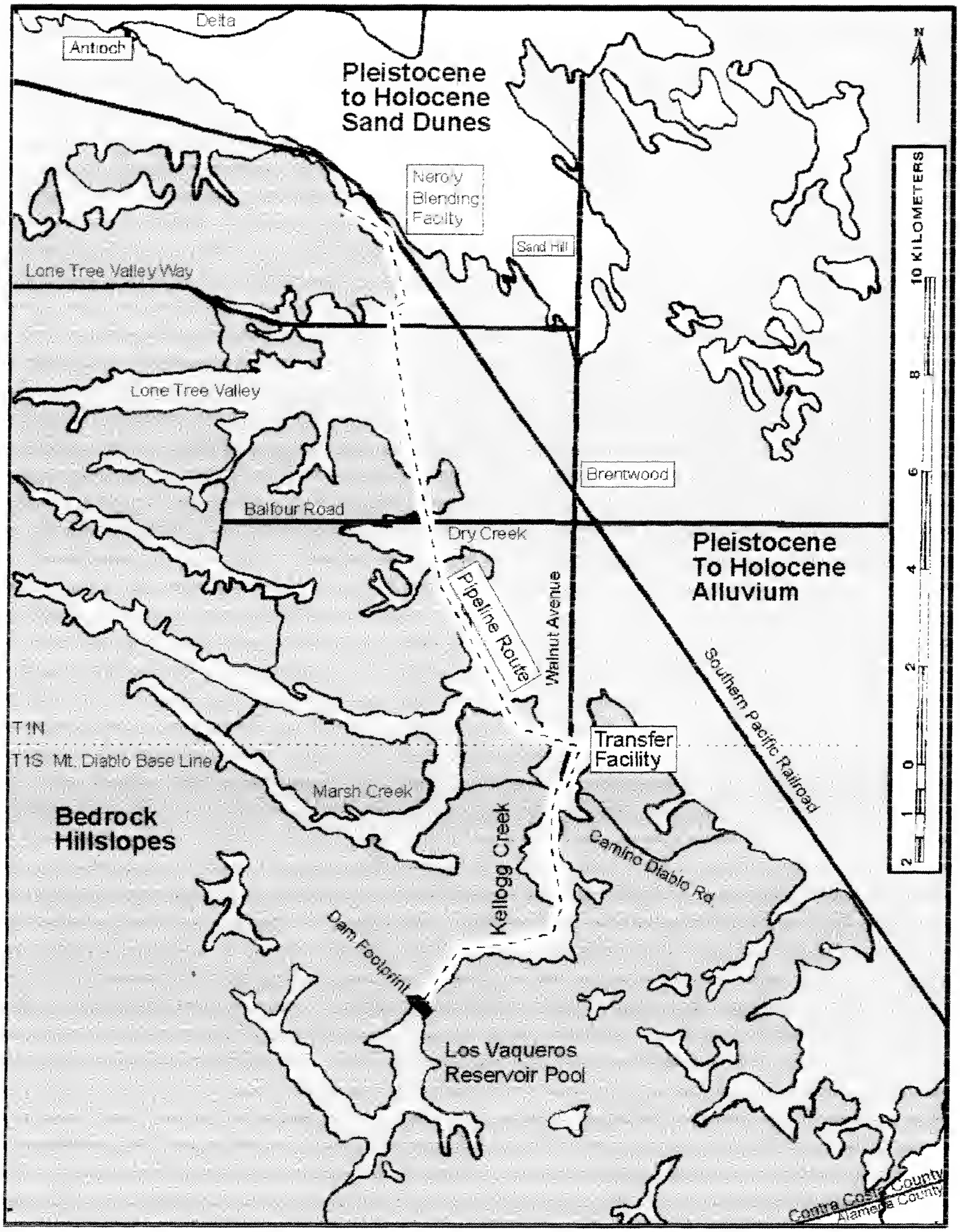


FIGURE 6. DISTRIBUTION OF BEDROCK HILLSLOPES AND ALLUVIAL VALLEYS (adapted from Helley et al. 1979: Plate 2 and 3)

they are more likely to contain buried paleosols and archaeological materials than the hillslope segments.

TABLE 2. Length of Pipeline Landscape Segments

Landscape Segments	Valley Segments	Hillslope Segments	Length
Upper Kellogg Creek	X		3.2 km
Middle Kellogg Creek	X		2.0 km
Camino Diablo Hillfront		X	0.4 km
Lower Kellogg Creek	X		1.2 km
Domengine Plateau		X	2.0 km
Marsh Creek	X		1.2 km
Older Alluvial Hills		X	3.6 km
Balfour Road	X		0.8 km
Lone Tree Valley	X		2.8 km
Wolfskill Foothills		X	2.0 km
Lindsey Basin	X		0.8 km
Wolfskill Uplands		X	0.8 km
Total Lengths	12.0 km	8.8 km	20.8 km

On the basis of the literature search, it was determined that subsurface archaeological survey would not be required in the hillslope segments that make up 42% of the Pipeline Route. The hillslope segments consist of deposits that predate human existence, and as such, they represent areas where erosion has been the dominant geological process. Soil that mantles the hillslopes is formed by the in-place weathering of deposits and the movement of colluvial materials downslope. The formation and burial of stable land surfaces are discouraged by the continuous movement and erosion of deposits that mantle the hillslopes. Likewise, the systemic context of archaeological materials associated with the hillslopes is likely to be disturbed or destroyed by these processes. Given these factors, the hillslopes segments were excluded from

the subsurface survey due to the lack of potential for buried archaeological deposits (Table 2).

The occurrence of watercourses was also noted in each segment of the Pipeline Route. The landuse patterns and settlement locations of prehistoric animals and people were likely influenced by the availability of fresh water. Based on the assumption that active watercourses may have served as a focal point for human landuse, more archaeological materials would be expected in those portions of a landscape located near present or former watercourses than the remaining portions of the same landscape. It is also likely that periodic overbank flooding and sediment deposition along active watercourses' results in the burial of any archaeological materials deposited on the adjacent floodplains. Following this reasoning, segments that contained present or potentially buried watercourses were also targeted for subsurface survey.

Despite the fact that the Old River Pipeline is located within the delta floodplain (Figure 1), the route was not included in the subsurface survey for the following reasons: (1) the route consists primarily of thick deposits of relatively recent alluvium that are unlikely to contain paleosols (Atwater 1982; Mark Group 1992; Page 1986; West 1977); (2) the thickness of the alluvium exceeds the depth that can be reached using a backhoe; (3) the high ground water levels along the route would likely prohibit the subsurface deposits to be examined safely or effectively; and (4) the design specifications suggest that the depth of the pipeline excavation is not likely to exceed the depth of the relatively recent alluvium (Mark Group 1992; Montgomery Watson 1994). Consequently, it was determined that there is a lack of potential for buried archaeological materials along the Old River Pipeline Route.

Field Methods

The field investigations involved a preliminary field check to confirm the accuracy of published information and to examine natural cutbanks and excavated exposures for buried paleosols and archaeological materials. Test trenches were excavated using a tractor-mounted backhoe at 26 individual locations in or near the Pipeline Route as marked by survey stakes at the time of the field work. The amount of trenching in any one segment was constrained to various degrees by conditions of property access, environmental clearance, and the nature and/or extent of the deposit. The dimensions of each trench were from 450-760 cm in length, 210-450 cm in depth, and at least 60 cm in width. The location of the test trenches excavated in each segment are shown in Figure 7, and listed in Appendix C.

The stratigraphic relationship of alluvial landforms along the Pipeline Route was tested in the field by physically examining the deposits exposed in the test trenches. The occurrence of archaeological materials was determined by spot checking the deposits as they were removed from test trenches and by examining trench cross sections whenever practical. The depth and general nature of the deposits were recorded in the field, with additional attention given to those deposits that contained buried paleosols or archaeological materials. The initial findings were used to further develop and refine survey strategies while still in the field. Specific locations were later targeted to determine the presence or absence of buried archaeological materials and to establish the sequence of landform-sediment assemblages.

Buried paleosols were recognized in the field on the basis of color, structure, horizon development, bioturbation, lateral continuity, and the nature of the upper boundary or contact with the overlying deposit, as described by Birkeland, Machette, and Haller (1991) and Retallack (1988). Buried paleosols

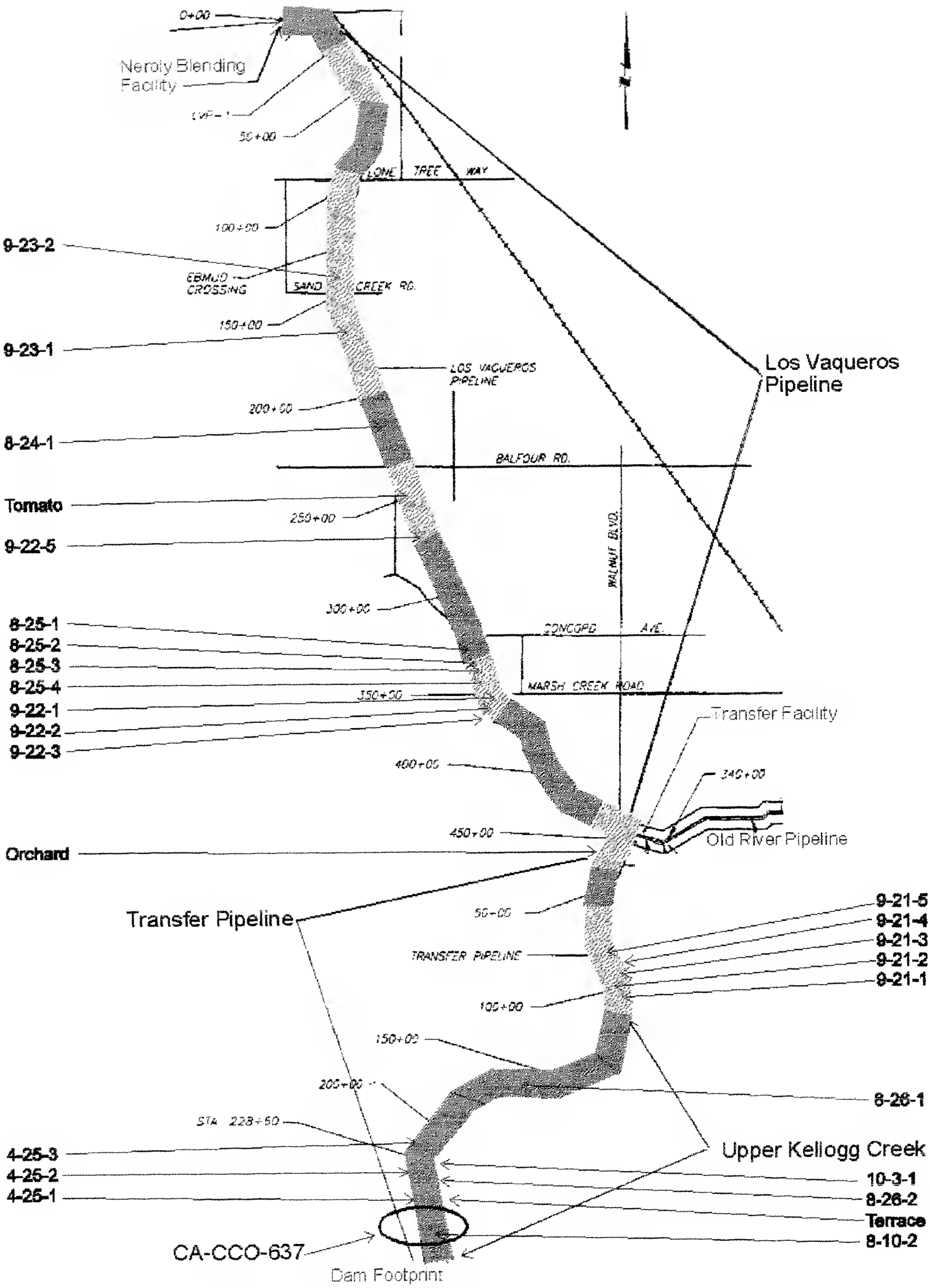


FIGURE 7. LOCATION OF TEST TRENCHES ALONG THE PIPELINE ROUTE

may or may not have exhibited an A horizon darkened by organic matter. In the case of truncated paleosols, the A horizon had been removed by erosion. Generally, the accumulation of clay or carbonates in the paleosol creates a B horizon that exhibits a distinct angular blocky structure. Paleosols often exhibit inactive root or insect holes and other indications of bioturbation. Since paleosols form during periods of pervasive land stability, the upper boundary of a buried paleosol represents a stratigraphic unconformity that is often marked by an abrupt upper boundary, or in some cases, stone lines. Paleosols generally exhibit extensive lateral continuity over large areas that can be used as stratigraphic markers. Additional definitions of soil and paleosols are given in Appendix B.

Laboratory Methods

Soil and sediment samples were collected from selected locations so that detailed analysis and description could be performed in the laboratory. The analysis of these samples was conducted to: (1) determine the relative percentages of sand, silt, and clay in a deposit; (2) determine the pH of a deposit; (3) identify depositional environments; (4) assess the degree of pedogenesis; and (5) facilitate stratigraphic correlation among depositional units.

The texture of the deposits was determined through a particle size analysis using the hydrometer method (Foth et al. 1982). The acidity or alkalinity (pH) of the deposits was determined using a VWR Model 55 Digital Mini-pH Meter, in a 1:1 mixture -- 20 grams of deposits to 20 grams distilled water (Singer and Janitzky 1986). Standardized reporting techniques and terminology were used to described the soil and sediment samples (Birkeland,

Machette, and Haller 1991; Soil Survey Staff 1975). The results of the soil and sediment analysis are described in Appendix D.

The age of particular deposits was established by submitting 10 samples to Beta Analytic, Inc., for C-14 analysis. Individual samples were initially given a project designation (LVAP #) before being assigned a number (Beta-#) by the laboratory. Radiocarbon results were corrected to calendar (cal) years before the present (B.P.) using the calibration program developed by Stuiver and Reimer (1993). The results of calibrated and uncalibrated radiocarbon analysis are summarized in Table 3. Additional radiocarbon sample data are presented in Appendix E.

Estimating Buried Potential

The potential for buried archaeological resources were estimated on the basis of the following criteria: (1) the presence or absence of a paleosol buried at some time during the Holocene; (2) the apparent preservation or erosion of the surface of a buried paleosol; (3) the relative or absolute time interval of landform stability (pedogenesis) represented by a paleosol; (4) the presence or absence of a present or former watercourse; and (5) the relative proximity of a buried paleosol to a present or former watercourse. The buried archaeological potential of each portion of the Pipeline Route was rated using the qualitative application of these criteria to the actual conditions observed in the field.

The following factors were considered to increase the potential for buried archaeological materials: (1) the occurrence of at least one paleosol buried during the Holocene; (2) the preservation of a buried paleosol surface; (3) the longer the amount of paleosol stability (time) before burial; (4) the occurrence of a present or former watercourse; (5) the proximity of a buried paleosol and a present or former watercourse; and (6) the occurrence of archaeological

materials associated with the same landform-sediment assemblage at nearby locations.

The following were considered to decrease the potential for buried archaeological materials: (1) the absence of a paleosol buried during the Holocene; (2) the presence of a buried paleosol that has been truncated by erosion; (3) areas that contain a buried paleosol but lack evidence of a present or former watercourse.

Areas were estimated to lack the potential for buried archaeological resources if they did not contain a paleosol buried during the Holocene. Areas were estimated to have a low potential for buried archaeological resources if they contained an intact paleosol buried during the Holocene. Areas were estimated to have a moderate potential for buried archaeological resources if they contained an intact buried Holocene paleosol near a present or former watercourse. Areas were estimated to have a high potential for buried archaeological resources if they contained archaeological materials associated with an intact buried Holocene paleosol.

CHAPTER 5

SUBSURFACE SURVEY FINDINGS

Introduction

In the following discussion, the findings from the subsurface survey are reported for each of the valley landscape segments as they occur from south to north in the project area. These segments were targeted for subsurface survey based on the methods outlined in Chapter 4. Each landscape segment is depicted in Figure 5 and described in Appendix A. The goals of the field survey were: (1) to test the accuracy of previously published information regarding the soils, geology, and landforms in each valley segment; (2) to locate, identify, and date buried paleosols and/or channels that could have been used by people in the past; (3) to locate, identify, and date buried archaeological materials; and (4) to determine the sequence of landform-sediment assemblages in different segments of the project area.

Upper Kellogg Creek: Upstream Section

Seven trenches were excavated in the upstream section of the Upper Kellogg Creek Segment: three to the west of the former Vasco Road and four to the east of the former Vasco Road (Appendix C). The segment is subdivided into upstream, midstream, and downstream sections as defined in Appendix A

One previously recorded prehistoric site, CA-CCO-637, is located within a gently sloping alluvial fan in this segment, just north of the Dam Footprint in the Spillway and Stilling Basin area. Geoarchaeological testing and archaeological excavation at the site revealed a concentration of intact archaeological materials buried at a depth of 60 - 150 cm below the present ground surface (Figure 8). The remains of 24 prehistoric Native American

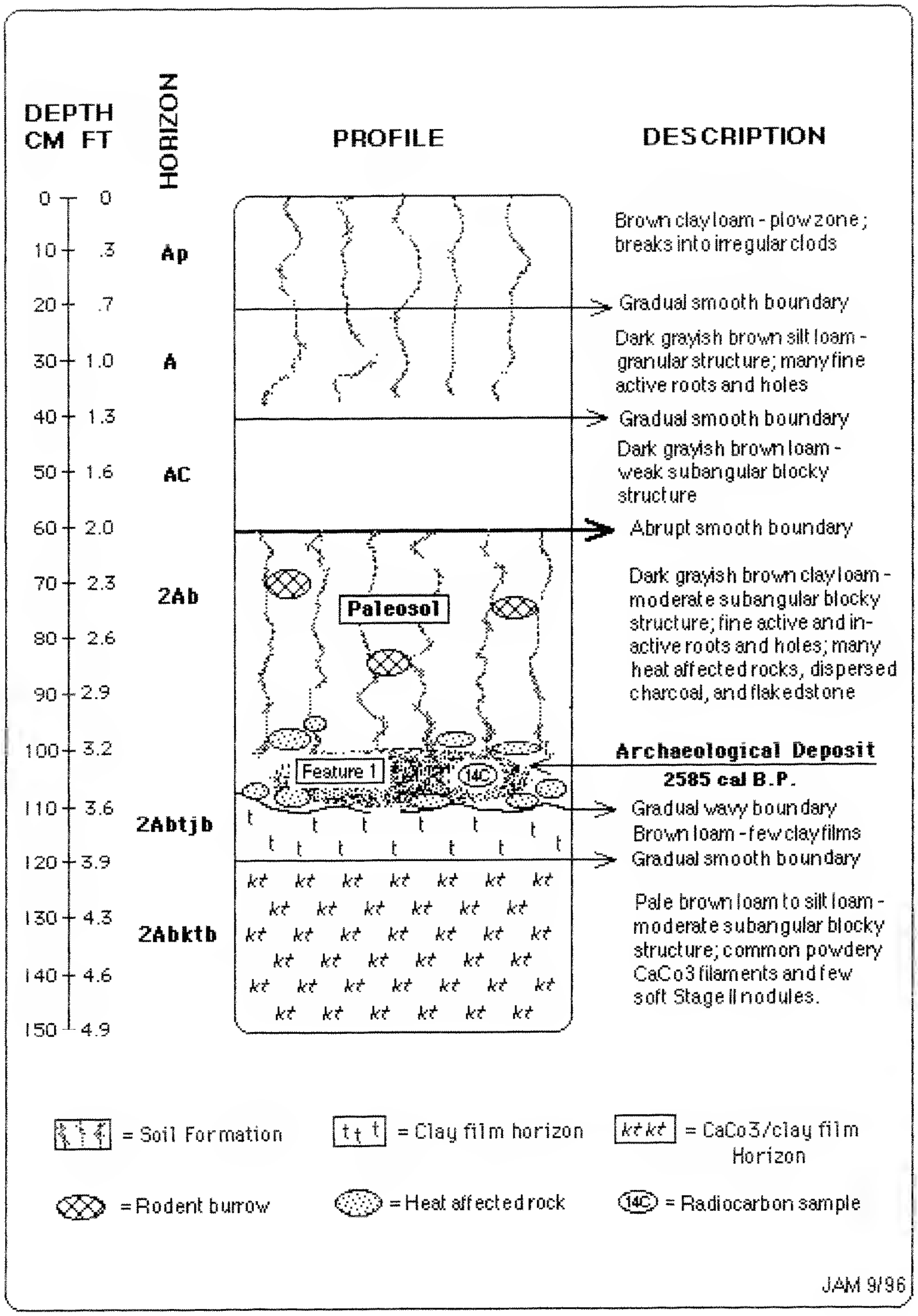


FIGURE 8. REPRESENTATIVE PROFILE OF DEPOSITS AT CA-CCO-637

burials have been identified and removed from the site as of September 1996. A radiocarbon age of 2500 +/- 100 B.P. (Beta-77470; wood charcoal) or 2585 cal B.P. was obtained from a fire hearth (Feature 1) at this site that was buried beneath 100 cm of sediment. The age and depth of this buried feature indicates that a significant amount of alluvium was deposited on the fan some time after 2500 B.P.

A single test trench (8-10-2) was excavated east of the former Vasco Road in the distal portion of the fan. Buried archaeological material (heat-altered rock) was observed 60 cm below the surface in association with a paleosol, confirming that the boundary of site CA-CCO-637 extends east of the former Vasco Road. Given the occurrence of intact archaeological materials and human remains directly associated with a paleosol, the potential of encountering additional buried archaeological deposits during pipeline construction in this area are extremely high.

In the remaining portion of the route that lies west of the former Vasco Road, test trenches were excavated in three separate alluvial fan deposits located near the base of the hillslopes. Each of the alluvial fans consists of clay-rich sediments that exhibit a single, well-developed soil profile. No paleosols were identified in any of the three fans tested. The presence of well-developed soils and the absence of paleosols in these fans suggests that they are at least Pleistocene in age. There is a lack of potential for buried archaeological material in these fans since they appear to predate human settlement of the area.

Three test trenches were excavated near historic site CA-CCO-447/H, where possible prehistoric cultural materials had been identified in a geotechnical test pit (WWC No. LLVEP-2) at a depth of 250 cm (Earth Sciences Associates 1992). The original test pit was relocated and re-excavated to the

same depth to access the same deposits that were reported to contain cultural material. Several naturally occurring fresh-water mussel shells were recovered from the same depth as originally reported during geotechnical trenching. Although a few pieces of flaking debris were found in the upper alluvium, no formal artifacts or significant concentration of archaeological materials was identified as a result of subsurface testing.

Although a paleosol was found to occur at a depth of 275 cm at this location, the upper portion had been removed by erosion before being capped by younger deposits (Figure 9). The horizontal extent and profile development of surface soil in the floodplain of the upstream section agree with the distribution and description of the Brentwood clay loam soil as mapped by Welch (1977). The weakly to moderately developed profile of the soil formed in the upper alluvium suggest that it is late Holocene in age. Archaeological materials that may have been associated with the paleosol have since been removed or redeposited by erosive processes along the creek channel. Consequently, there is a lack of potential for intact archaeological material to be buried in this portion of the upstream section.

One of the trenches excavated near site CA-CCO-447/H exposed the scour and fill relationship of two stream terraces along Kellogg Creek. The lower terrace is inset below the upper terrace, indicating that it is younger that the upper (late Holocene) terrace (Figure 9). Furthermore, the lower terrace exhibits an incipient soil profile as compared to the upper terrace, which exhibits a weakly developed soil profile. Since the lower terrace was likely formed in relatively recent historic times, it appears that there is no potential for it to contain intact concentrations of buried prehistoric archaeological materials.

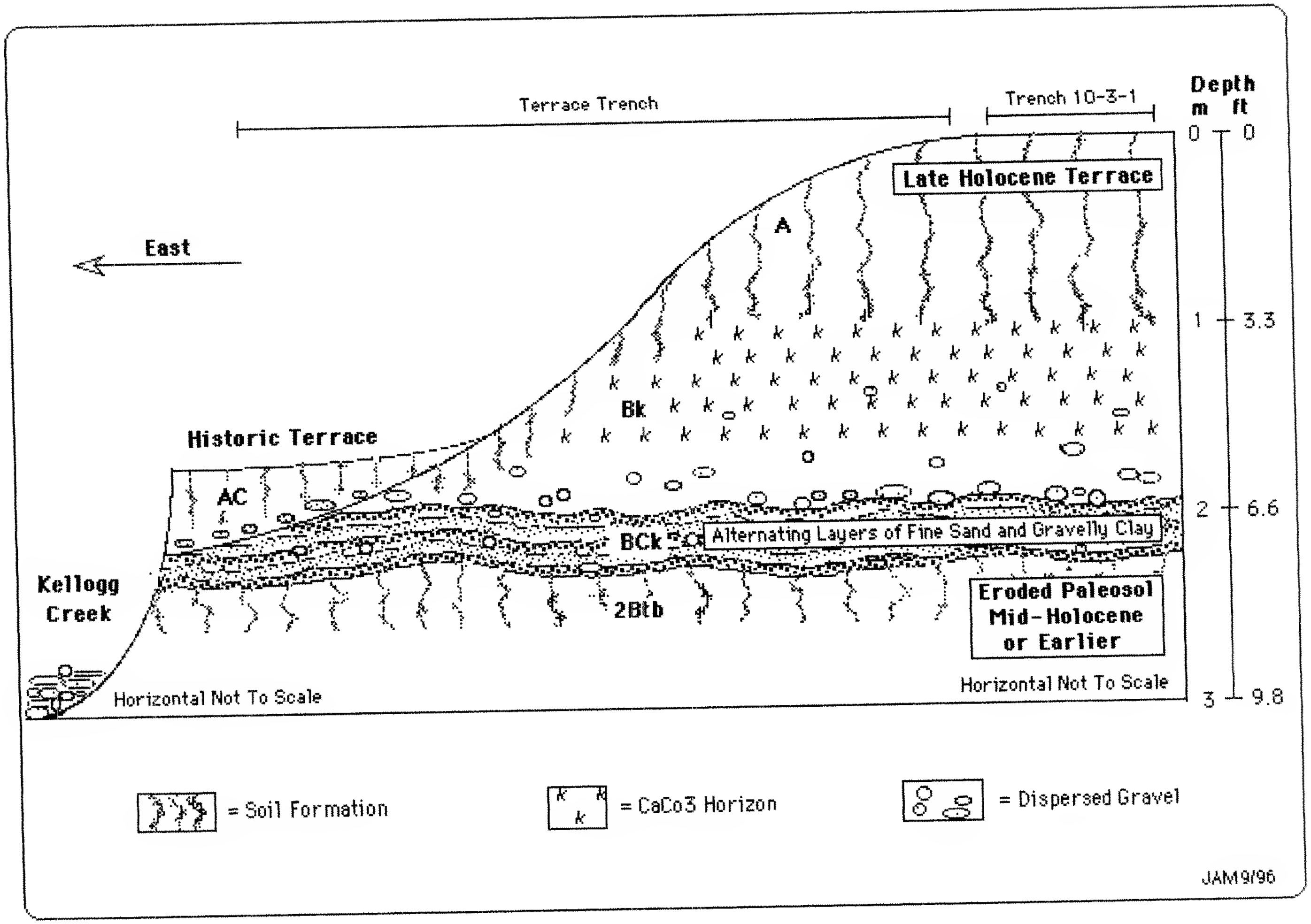


FIGURE 9. LANDSCAPE-SEDIMENT ASSEMBLAGE IN UPSTREAM SECTION OF UPPER KELLOGG CREEK

Upper Kellogg Creek: Midstream Section

A single test trench was excavated south of the former Vasco Road and north of Kellogg Creek in the midstream section of the segment. This trench was located across the contact of two stream terraces that border Kellogg Creek. The trench revealed that the lower terrace has filled a scoured portion of the upper terrace, indicating that it is younger than the upper terrace (Figure 10). Besides exhibiting an incipient soil profile, the lower terrace was found to contain several fragments of historic bottle glass and a cow tooth. These historic materials are assumed to be associated with historic archaeological site CA-CCO-446H, which is located nearby in this section. Since the lower terrace has obviously formed during recent historic times, it appears that there is no potential for intact concentrations of prehistoric archaeological materials to be buried in this portion of the midstream section.

By comparison, the upper terrace was found to contain a single, well-developed soil profile indicating that it has remained stable for a considerable amount of time. The horizontal extent and profile development of the upper terrace agree with the distribution and description of the San Ysidro loam soil as mapped by Welch (1977). Since neither of the stream terraces north of Kellogg Creek was found to contain a paleosol, there is little of no potential for encountering buried archaeological material in this portion of the midstream section of the segment.

A well-developed paleosol was identified and traced laterally in a few cutbanks exposed along the south side of Kellogg Creek. The paleosol, which lies at a depth of 120-180 cm below the surface and is overlain by younger alluvium with a moderately developed profile, appears to be restricted to the floodplain south of Kellogg Creek (Figure 10). Unlike the eroded paleosol in the upstream section, the surface of the paleosol remains intact in this area, and

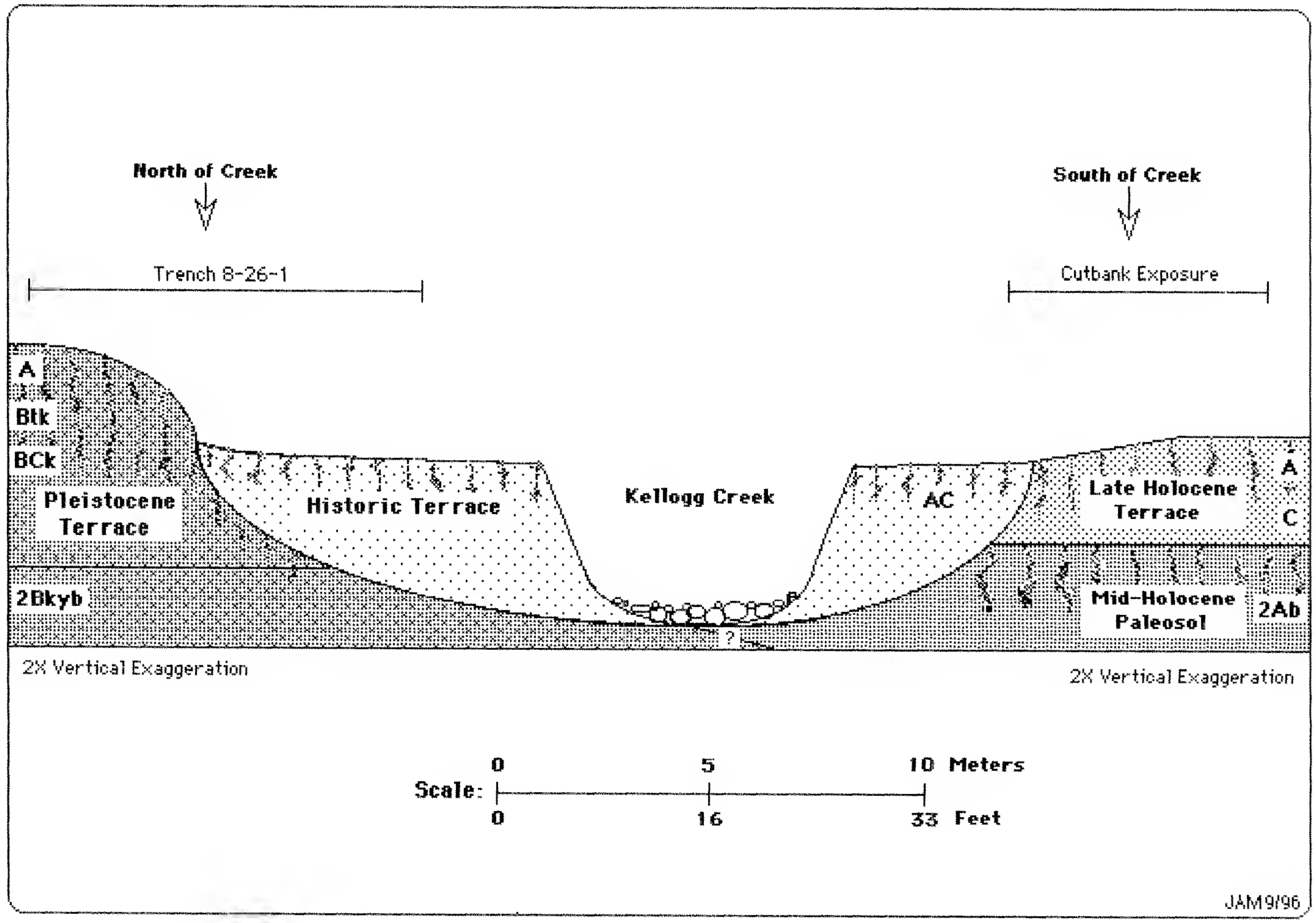


FIGURE 10. LANDSCAPE-SEDIMENT ASSEMBLAGE IN MIDSTREAM SECTION OF UPPER KELLOGG CREEK

has potential for containing buried archaeological material. This area has since been excluded from the proposed Pipeline Route due to subsequent design changes (Montgomery Watson 1994).

Upper Kellogg Creek: Downstream Section

Test trenches were not excavated in the downstream section because the section contains landform-sediment assemblages that were tested elsewhere along the route. The majority of the downstream section has a low potential for containing buried archaeological materials since it appears to have the same landform-sediment assemblage as the area north of Kellogg Creek in the midstream section. However, a small area near the base of the hillslopes west of the former Vasco Road and southwest of Kellogg Creek appears to have the same landform-sediment assemblage as the Middle Kellogg Creek Segment that was found to contain an intact paleosol (see Middle Kellogg Segment). Since it is likely that an intact paleosol is present in a small part of this section, the potential for buried archaeological material is low to moderate.

Summary of Upper Kellogg Creek Segment

A high potential for buried archaeological materials exists in a small portion of the upstream section (the alluvial fan in the Spillway Stilling Basin area that contains site CA-CCO-637), because intact concentrations of archaeological materials, including human graves, have been identified in association with a paleosol by previous investigations in this area (Meyer 1995).

A low to moderate potential for buried archaeological material exists in a small portion of the downstream section of the segment (near the base of the hillslopes west of the former Vasco Road and southwest of Kellogg Creek),

because it appears to have a landform-sediment assemblage that is likely to contain a paleosol in proximity to a known watercourse.

A lack of potential for buried archaeological materials exists in the remaining portions of the Upper Kellogg Creek Segment where pipeline construction is planned. This is because most of the landform-sediment assemblages appear to have remained stable since at least the late Pleistocene, and are therefore too old to contain buried archaeological materials. In those portions of the route near the Kellogg Creek channel where paleosols were identified, the upper surface of the paleosol and any associated archaeological materials appear to have been removed and/or redeposited by erosive processes.

Middle Kellogg Creek Segment

Five test trenches were excavated between Kellogg Creek to the West and the former Vasco Road to the East in this segment. Small areas of slightly elevated, older soils were identified and mapped as Altamont clay loam by Carpenter and Cosby (1939). Trenches excavated in two of the elevated landforms revealed that they consist of older alluvium that exhibits a single, well-developed soil profile (Figure 11). The degree of profile development of these landforms is quite similar to the San Ysidro loam formed on the upper terrace in the Midstream section of the Upper Kellogg Creek Segment. Although a sample taken from the older alluvium lacked sufficient carbon for radiocarbon analysis (Beta-79408), the deposit is estimated to be Pleistocene in age based on the strong development of the profile. The potential for buried archaeological material in the older alluvium is low; however, archaeological materials may have been buried on those portions of the older landforms that are now overlain by younger alluvium.

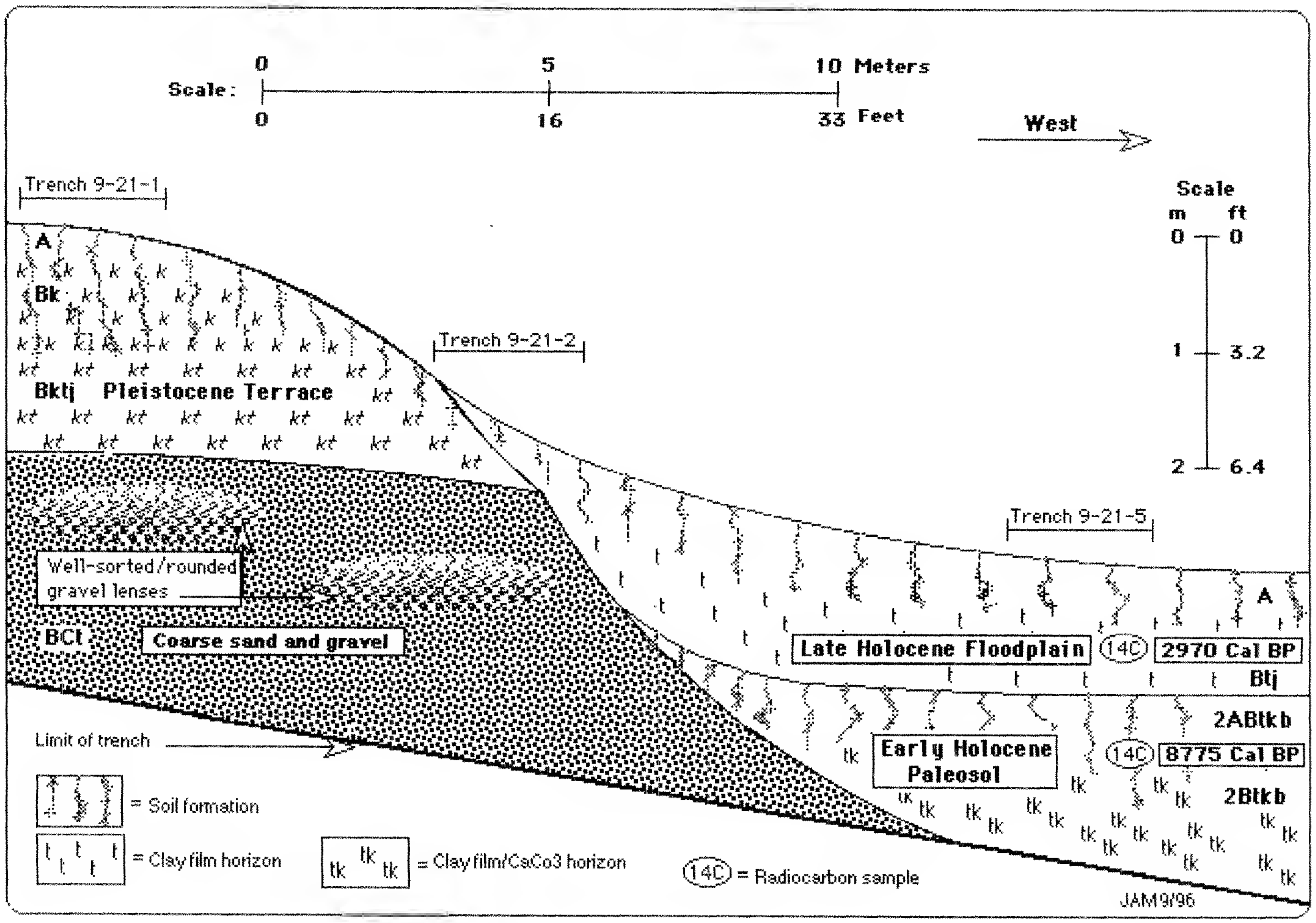


FIGURE 11. LANDSCAPE-SEDIMENT ASSEMBLAGE IN MIDDLE KELLOGG CREEK SEGMENT

Test trenches were excavated at three locations in the nearly level floodplain that makes up the majority of this segment. An intact paleosol was found to occur at a depth of 137 cm below the present ground surface in the middle reaches of the floodplain (Figure 11). A radiocarbon age of 7980 +/- 130 B.P. (Beta-79409; soil humate) or 8775 cal B.P. was obtained from a sample of the paleosol. A radiocarbon age of 2880 +/- 80 B. P. (Beta-79410) or 2970 cal B.P. was obtained from the alluvium that immediately overlies the paleosol. The overlying alluvium exhibits a moderately developed soil profile that agrees more closely with the description for Brentwood sandy clay loam given by Carpenter and Cosby (1939:54) than with the Rincon clay loam of Welch (1977:42). The radiocarbon age suggests that the paleosol formed on a stable floodplain more than 8,000 years ago. The floodplain remained relatively stable until it was buried by an episode of floodplain aggradation that began more than 3,000 years ago. The age of the paleosol and the overlying alluvium indicate that the floodplain remained stable and available for prehistoric human settlement for nearly 5,000 years. Given the partial burial of the older elevated landforms and the age and extent of the paleosol, there is a moderate potential that buried archaeological materials will be encountered in the alluvium of the Middle Kellogg Creek Segment.

Lower Kellogg Creek Segment

A single test trench was excavated in this segment immediately northwest of the intersection of Walnut Avenue and Camino Diablo Road. Trenching to a depth of 240 cm below the surface revealed a single, moderately developed soil profile formed in alluvium. The general nature and extent of the deposit are similar to an area of Holocene alluvium mapped by Helley et al. (1979) and Younger Marsh Creek alluvium mapped by Atwater (1982). The

horizontal extent and profile development of the surface soil in this segment were generally found to agree with the distribution and description of Brentwood clay loam as mapped by Carpenter and Cosby (1939) and of Rincon clay loam as mapped by Welch (1977). The degree of soil development closely compares with that found in the upper alluvium of Middle Kellogg Creek Segment, suggesting that it is also late Holocene in age. Since the Lower Segment probably shares a common depositional history with the Middle Segment, it is likely that a paleosol exists more than 240 cm below the surface of the Lower Segment. Further, the Pipeline Route closely parallels the present course of Kellogg Creek, increasing the likelihood that prehistoric people were attracted to the area. Consequently, there is a moderate potential that buried archaeological materials may be encountered in the alluvium of the Lower Kellogg Creek Segment.

Marsh Creek Segment

Test trenches were excavated at seven locations in the nearly level floodplain that makes up the most of this segment. Three of these trenches were excavated in the area south of Marsh Creek and four trenches were excavated in the area north of Marsh Creek. Three well-developed paleosols were identified in this segment: two south of the creek and one north of the creek (Figure 12). The two paleosols south of the creek occur at depths of 143 cm and 270 cm below the present ground surface. The paleosol north of the creek is exposed at the surface of the floodplain in the northernmost part of the segment, but is buried by younger alluvium as it dips toward Marsh Creek. The overlying alluvium on both sides of the creek exhibits a moderately developed soil profile. The general nature and extent of the upper alluvium are similar to an area of Holocene alluvium mapped by Helley et al. (1979) and with the

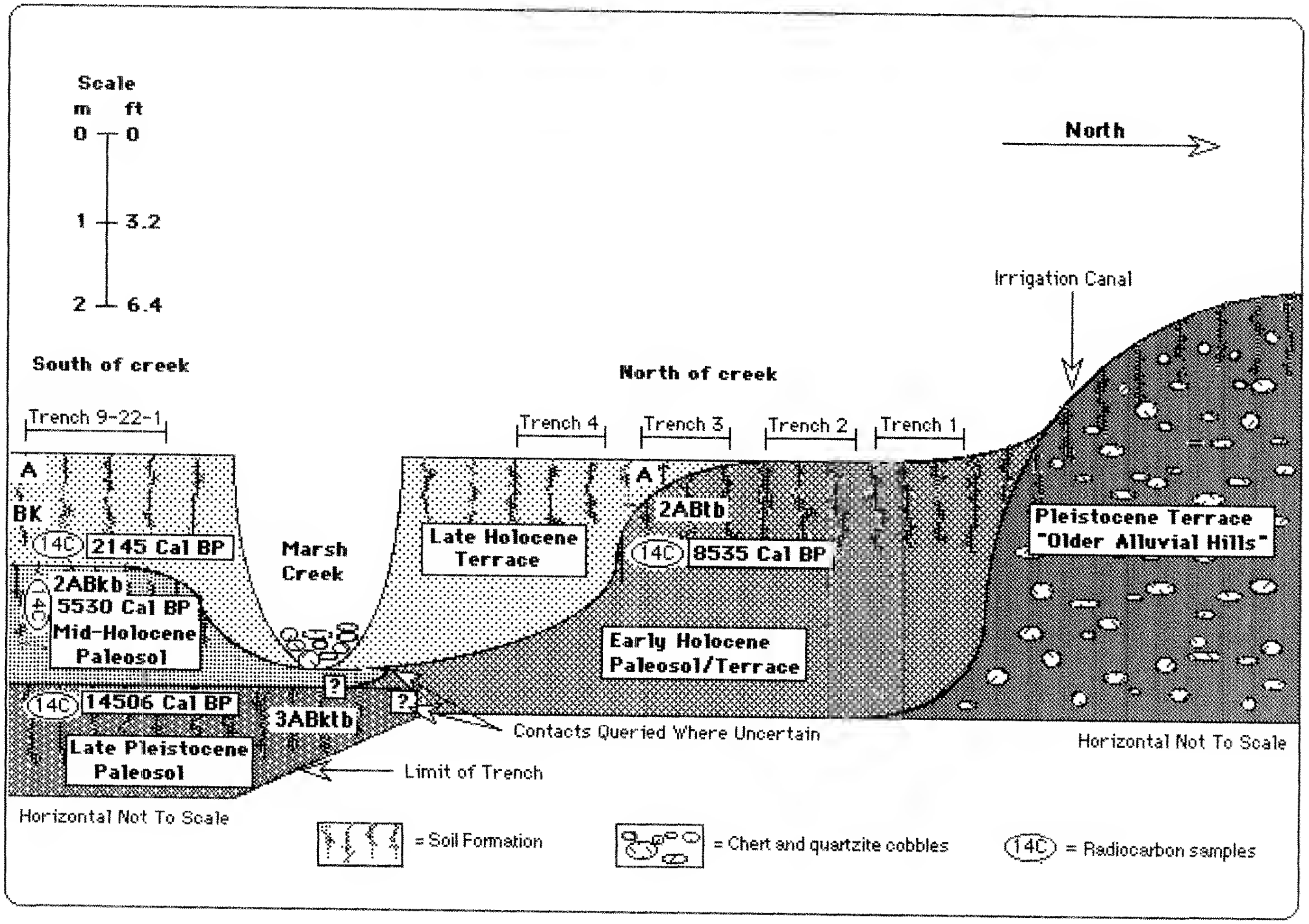


FIGURE 13. LANDSCAPE-SEDIMENT ASSEMBLAGE IN MARSH CREEK SEGMENT

younger alluvium of Marsh Creek mapped by Atwater (1982). The horizontal extent and profile development of the surface soil agree with the distribution and description of the Brentwood clay loam as mapped by Carpenter and Cosby (1939:53).

Three radiocarbon ages were obtained from samples taken from Trench 9-22-1 located south of Marsh Creek, (1) 12,400 +/- 150 B.P. (Beta-79405; soil humate) or 14,506 cal B.P.; (2) 4760 +/- 70 B.P. (Beta-79406; soil humate) or 5530 cal B.P.; and (3) 2180 +/- 70 B.P. (Beta-79407; soil humate) or 2145 cal B.P. The age of these deposits indicates that the southern portion of the floodplain experienced prolonged periods of stability during the late Pleistocene, the mid-Holocene, and the late Holocene. These ages suggest that archaeological materials ranging in age from late Pleistocene to mid-Holocene would be associated with the lower paleosol, while materials ranging from the mid-Holocene to the early part of the late Holocene would be associated with the upper paleosol. Archaeological materials no older than the later one-half of the late Holocene would be associated with the surface soil formed in the upper alluvium.

A radiocarbon age of 7810 +/- 220 B.P. (Beta-79404; soil humate) or 8535 cal B.P. was obtained from a paleosol located north of the creek (Trench 3), indicating that it is early Holocene in age (Figure 12). On the basis of the age and the similarity of the surface soil with that found south of the creek, this portion of the Marsh Creek floodplain has undergone a prolonged period of stability that began in the early Holocene. This period gave way to renewed alluvial deposition and subsequent floodplain stability in the late Holocene. Archaeological material ranging in age from the early Holocene to the first one-third of the late Holocene may be associated with the partially buried paleosol north of the creek.

If prehistoric human settlement of the area began around 10,000 years ago, only about 2,500 years of the archaeological record is represented at or near the surface of the late Holocene alluvium in the Marsh Creek floodplain. In contrast, a 7,500-year portion of the archaeological record may be buried below the present floodplain of Marsh Creek. Given the nature and extent of the three paleosols, there is a moderate potential that buried archaeological materials may be encountered in the alluvium of the Marsh Creek Segment.

<u>Balfour Road Segment</u>

Three test trenches were excavated in this segment: one trench near the Older Alluvial Hills, one trench near Dry Creek, and one trench near Deer Creek to the North. The Older Alluvial Hills trench was excavated to a depth of 240 cm below the present ground surface. Trenching revealed a well-developed surface soil formed in alluvium at this location (Figure 13). A well-developed paleosol underlies the surface soil at a depth of 100 cm below the present ground surface. The paleosol contains many matrix-supported, subangular to subrounded chert and quartzite cobbles like the adjoining Older Alluvial Hills. Although a sample of the paleosol was submitted for radiocarbon-analysis, it lacked sufficient carbon for testing (Beta-79402). A radiocarbon age of 8050 +/- 80 B.P. (Beta-79403; soil humate) or 8965 cal B.P. obtained from the overlying soil, indicates that the paleosol is at least early Holocene in age. On the basis of the radiocarbon date and the similarity of the paleosol with the Older Alluvial Hills, the paleosol is estimated to be at least Pleistocene in age.

The general nature and extent of the early Holocene surface soil are similar to an area of Holocene alluvium as mapped by Helley et al. (1979). The horizontal extent and profile development of the surface soil also agree with the description and distribution of the Brentwood clay loam as mapped by

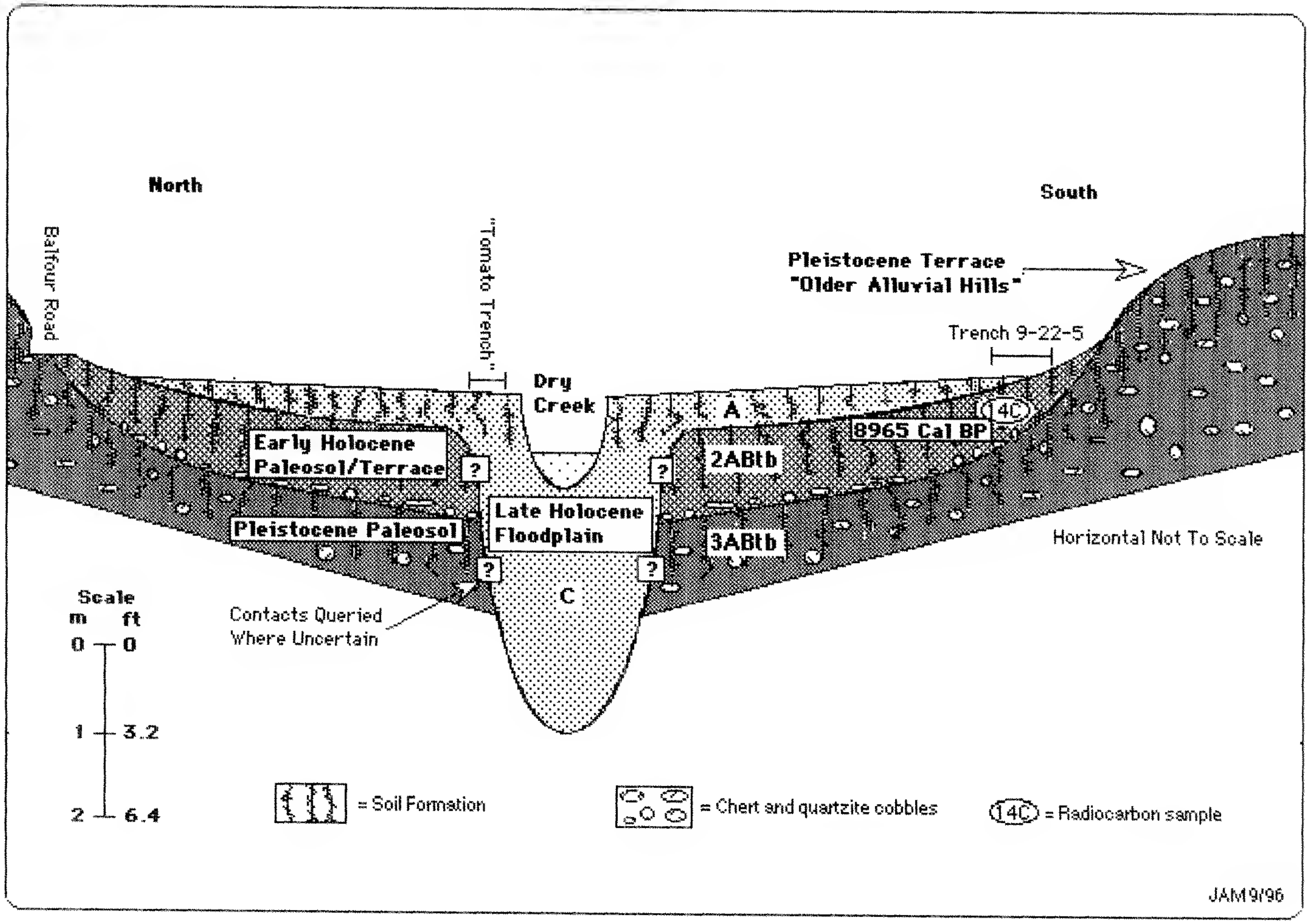


FIGURE 13. LANDSCAPE-SEDIMENT ASSEMBLAGE IN DRY CREEK AREA OF BALFOUR ROAD SEGMENT

Carpenter and Cosby (1939:53) and the Rincon clay loam as mapped by Welch (1977).

A single trench (Tomato Trench) was excavated to a depth of 380 cm below the present ground surface near Dry Creek. A weakly developed soil profile formed in alluvium was identified at this location (Figure 13). The general nature and extent of the alluvium are similar to an area of Holocene alluvium as mapped by Helley et al. (1979). The horizontal extent and profile development of the surface soil agree with the description and distribution of the Brentwood clay as mapped by Carpenter and Cosby (1939). Although the deposit was not radiocarbon-dated, it is estimated to be late Holocene in age based on the moderate development of the soil profile and its geomorphic position. Subsequent excavation of the Pipeline Route revealed that a well-developed paleosol occurs at a depth of 600 cm below the surface. It appears that the early Holocene soil identified near the valley margin extends beneath a deposit of late Holocene alluvium in the central part of the Dry Creek floodplain.

An examination of the Deer Creek trench revealed a single, well-developed soil formed in alluvium to a depth of 300 cm below the present ground surface. No paleosols were observed or identified at this location. While this portion of Deer Creek was not mapped by Helley et al. (1979); it was mapped by Atwater as being Younger Marsh Creek alluvium (1982). The horizontal extent and profile development of the surface soil agree with the description and distribution of the Capay clay as mapped by Welch (1977). Although radiocarbon ages were not obtained from the deposits at Deer Creek, the alluvium is estimated to be Pleistocene in age and therefore predates known human settlement of the region. Since archaeological materials are expected to occur at or near the surface of Pleistocene landform-sediment

assemblages, there is a lack of potential for these materials to be buried in the alluvium of Deer Creek.

Since the Pleistocene paleosol is partially buried, 1,000 years of the archaeological record may be buried by the early Holocene soil (8965 cal B.P.) in this area. Likewise, the early Holocene soil is partially buried by late Holocene alluvium in the central part of the valley. If the late Holocene alluvium is at least 3,000 years in age, then as much as 7,000 years of the archaeological record may be buried beneath the Dry Creek floodplain. This means that only the last 3,000 years of the archaeological record would be expected to occur at or near the surface of the central part of the floodplain. Given the nature and extent of the deposits, there is a moderate potential that buried archaeological materials may be encountered in the Dry Creek portion of the segment. There is a lack of potential for buried archaeological materials in the Deer Creek area, since the landform-sediment assemblage in that portion of the segment appears to predate human settlement.

Lone Tree Valley Segment

Test trenches were excavated at two locations in this segment, one in the southern part of the Sand Creek floodplain and another next to the present channel of Sand Creek. In the southern part of the floodplain, a trench was excavated to a depth of 450 cm below the present ground surface (Figure 14). At this location, a moderately developed surface soil was found to overlie a well-developed paleosol at a depth of 220 cm. A separate well-developed paleosol was found underlying the alluvial package of the upper paleosol at a depth of 440 cm. The general nature and extent of the upper alluvium are similar to an area of Holocene alluvium as mapped by Helley et al. (1979). The horizontal extent and profile development of the surface soil agree with the

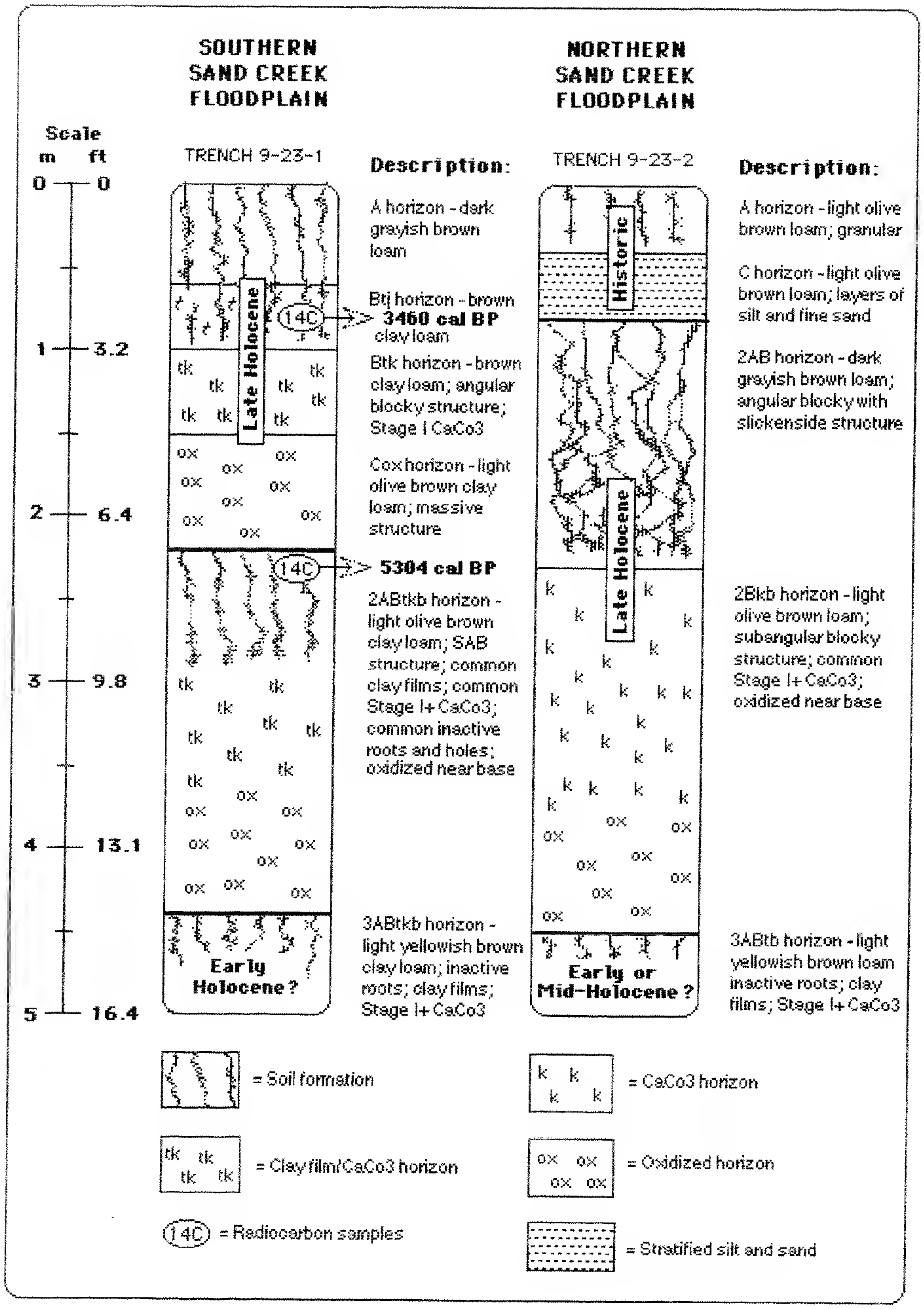


FIGURE 14. PROFILES IN THE LONE TREE VALLEY SEGMENT

description and distribution of the Brentwood clay loam as mapped by Welch (1977).

A radiocarbon age from the upper alluvium of 3250 +/- 80 B.P. (Beta-79401; soil humate) or 3460 cal B.P. indicates that it is late Holocene in age, while an age of 4590 +/- B.P. (Beta-79400; soil humate) or 5304 cal B.P. obtained from the upper paleosol indicates that it is Mid-Holocene in age. Although an attempt was made to date a sample from the lower paleosol, the carbon content of the sample (Beta-79399) was insufficient for testing. The age of the lower second paleosol is estimated to be at least early Holocene, based on the similarity of the overlying sequence with that identified south of Marsh Creek (see Figure 12).

Near Sand Creek, a trench was excavated to a depth of about 450 cm below the ground surface (Figure 14). An unweathered surface soil, formed in stratified alluvium, was found to extend to a depth of 80 cm. The upper alluvium overlies a moderately developed paleosol which in turn overlies a lower well-developed paleosol at a depth of 440 cm. The general nature and extent of the upper alluvium are similar to an area of Holocene alluvium mapped by Helley et al. (1979). The horizontal extent and profile development of the surface soil agree with the description and distribution of the Sorrento clay loam as mapped by Carpenter and Cosby (1939:53) and the Sycamore silty clay as mapped by Welch (1977).

The upper alluvium at Sand Creek is historic to recent in age based on the occurrence of historic debris (metal cans, clear glass, and white earthenware) found buried within the deposit. The paleosol underlying the historic alluvium is estimated to be late Holocene in age based on moderate development of the soil profile and stratigraphic position. The lower paleosol is

estimated to be mid-Holocene in age or older based on its stratigraphic position and well-developed soil profile.

If buried archaeological materials of early and mid-Holocene age are encountered, they will be associated with one of the two paleosols buried by late Holocene alluvium in the Sand Creek floodplain. If buried archaeological materials of late Holocene or historic age are encountered, they will be associated with the upper paleosol buried by recent sediments near Sand Creek. Given the age and extent of the paleosols in the Sand Creek floodplain, there is a moderate potential that buried archaeological materials may be encountered in the Lone Tree Valley Segment.

Lindsey Basin Segment

Due to the presence of a previously excavated exposure, no test trenches were excavated in this segment. The exposure, part of an existing canal route, had been excavated to a depth of about 490 cm below the present ground surface. An examination of the exposed deposits revealed a single, well-developed soil profile. No paleosols were identified at this location. The general nature and extent of the alluvium are similar to an area of Pleistocene alluvium as mapped by Helley et al. (1979). The horizontal extent and profile development of the surface soil agree with the description and distribution of the Capay clay as mapped by Welch (1977).

Although no radiocarbon ages were obtained from this location, the alluvium of the basin is probably Pleistocene in age. Since the landform-sediment assemblage predates known human occupation of the area, there is a lack of potential for buried archaeological materials to occur in the Lindsey Basin Segment.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Summary

This study has examined the soils and sediments contained in valleys of eastern Contra Costa County to estimate the potential for buried archaeological sites, and to assess the influence of landscape evolution on the structure of the archaeological record. Previous studies have found that the alluvium in many valleys of the region is relatively recent in age, and that comparatively few prehistoric sites occur at the surface of the valleys in the project area. Given this combination, it was hypothesized that wide-spread deposition may have buried the majority of land surfaces that were once available for human occupation in the valleys. This would mean that the present distribution of surface sites does not reflect the entire record of human use and settlement, but only represents those portions of the archaeological record that post-date the last major period of deposition in the valleys. To test this, a geoarchaeological investigation was initiated to locate buried land surfaces and estimate the potential for encountering buried archaeological resources during project construction.

Backhoe trenches were excavated in the valleys along the route to test for the occurrence of paleosols that may contain archaeological materials (Figure 7). Radiocarbon testing was performed to determine the age of the paleosols and to correlate the stratigraphic sequence of alluvium deposited in each of the floodplain segments along the route. Estimates of potential for buried sites were based on the occurrence of paleosols that would have been available within the span of known human settlement of the region, with higher potentials assigned for those areas where paleosols occur near present or former watercourses.

At least one or more paleosols were identified in five of the six valleys surveyed along the route (Upper Kellogg Creek, Middle Kellogg Creek, Marsh Creek, Balfour Road, and Lone Tree Valley). While no paleosol was identified in the Lower Kellogg Creek Segment, it is likely that the segment contains at least one paleosol since it appears to have the same landform-sediment assemblage as Middle Kellogg Creek. The paleosols were found to range in depth from 70 cm to 440 cm below the present ground surface, with an average depth of 164 cm. This is close to the average depth (141 cm) of buried sites found in the San Ramon Valley of western Contra Costa County. Although it was not possible to precisely determine their horizontal extent, it was determined that the paleosols have considerable lateral continuity within the floodplains crossed by the route. Nine of the ten dated paleosols were found to be Holocene in age (Table 3).

TABLE 3. Radiocarbon Analysis Results

C-14 age B.P.	cal years	Depth cm	Segment	Location	Beta-	LVAP
2180 +/- 70	2145 B.P.	115-134	South Marsh Cr.	9/22/01	79407	15
2500 +/- 100	2585 B.P.	97-110	Upper Kellogg Cr.	CA-CCO-637	77470	3
2880 +/- 80	2970 B.P.	70-79	Middle Kellogg Cr.	9/21/05	79410	18
3250 +/- 80	3460 B.P.	70-88	Lone Tree Valley	9/23/01	79401	9
4590 +/- 70	5304 B.P.	219-259	Lone Tree Valley	9/23/01	79400	8
4760 +/- 70	5530 B.P.	173-195	South Marsh Cr.	9/22/01	79406	14
7810 +/- 220	8535 B.P.	131-140	North Marsh Cr.	Trench 3	79404	12
7980 +/- 130	8775 B.P.	170-189	Middle Kellogg Cr.	9/21/05	79409	17
8050 +/- 80	8965 B.P.	24-40	Balfour Road	9/22/05	79403	11
12400 +/- 150	14506 B.P.	268-289	South Marsh Cr.	9/22/01	79405	13

Note: C-14 age calibrated to calendar (cal) years according to Stuiver and Reimer (1993).

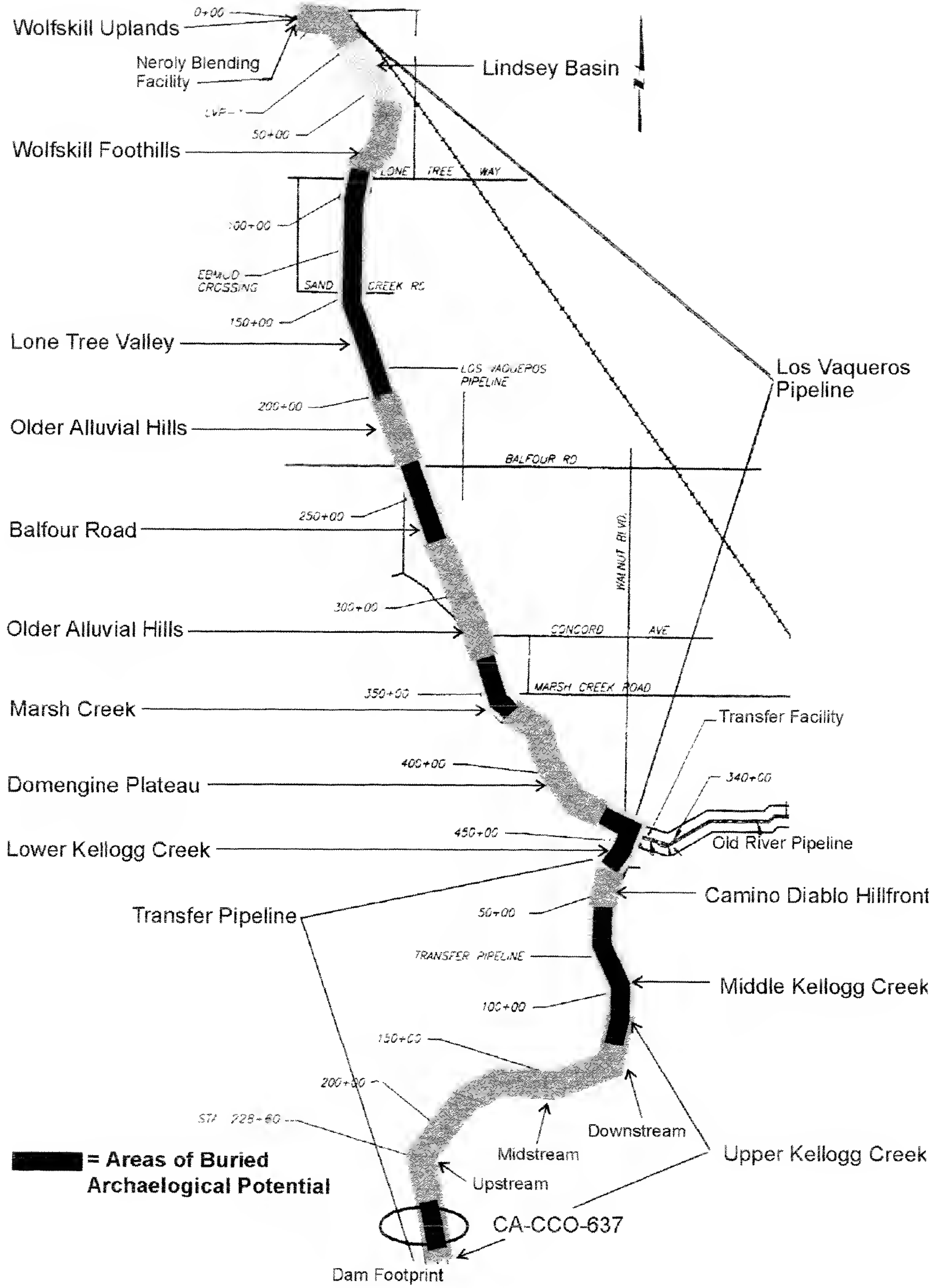


FIGURE 15. AREAS WITH THE POTENTIAL FOR

BURIED ARCHAEOLOGICAL RESOURCES.

Areas estimated to have the potential for containing buried archaeological materials are shown in Figure 15. The temporal range of potentially buried archaeological materials is summarized for each segment according to a three part division of the Holocene in Table 4 . The area estimated to have the highest potential of containing buried archaeological materials is near the northern toe of the Dam Footprint in the Upper Kellogg Creek Segment. Buried archaeological materials were identified at a depth of 60 cm below the surface in Trench 8-10-2 at this location (Figure 7). The buried archaeological materials occur near the eastern boundary of a previously recorded archaeological site (CCO-637). The occurrence of intact concentrations of archaeological materials in association with a paleosol makes it highly likely that additional archaeological materials are buried at this location. Given that a total of 24 human burials have so far been encountered in the area west of the former Vasco Road, it is likely that additional human remains will be encountered during earth-moving activities in the are that lies to the east of the former Vasco Road (Meyer 1995).

TABLE 4. Estimated Potential for Buried Archaeological Resources

LANDSCAPE SEGMENTS	Early Holocene	Middle Holocene	Late Holocene
Upper Kellogg Creek:			
upstream section	1	2	3
midstream section	0	0	0
downstream section	2	2	1
Middle Kellogg Creek	2	2	1
Camino Diablo Hillfront	0	0	0
Lower Kellogg Creek	2	2	1
Domengine Plateau	0	0	0
Marsh Creek Alluvium	2	2	1
Older Alluvial Hills	0	0	0
Balfour Road Alluvium	1	2	1
Lone Tree Valley	1	2	2
Wolfskill Foothills	0	0	0
Lindsey Basin Alluvium	0	0	0
Wolfskill Uplands	0	0	0

KEY: Lack Potential = 0 Low Potential = 1 Moderate Potential = 2 High Potential = 3

It is estimated that there is a moderate potential for buried archaeological materials in portions of six landscape segments: Upper Kellogg Creek; Middle Kellogg Creek; Lower Kellogg Creek; Marsh Creek; Balfour Road; and Lone Tree Valley (Table 4, see Figure 15). The moderate potential of these areas derives from the occurrence of at least one intact Holocene paleosol buried near a present or former watercourse. In the portions of these segments where an intact paleosol is not located near a present or former watercourse, the potential for buried archaeological material is low.

There is a lack of potential for buried archaeological material in the midstream section and most of the downstream section in the Upper Kellogg Creek Segment (Table 4). Although a paleosol was identified in a portion of the midstream section, the Pipeline Route has been realigned to avoid this area. The route will instead cross through a landform-sediment assemblage that does not contain a paleosol. The same is true for most of the downstream section of the Upper Kellogg Creek Segment, except for a small area west of the former Vasco Road, as shown in Figure 15. The hillslope segments and Lindsey Basin are believed to lack potential for containing buried archaeological materials (Table 4). Additional recommendations for the management of archaeological resources encountered along the Pipeline Route are outlined in Appendix F.

Conclusions

Radiocarbon analysis indicates that one or more paleosols of Pleistocene or Holocene age is buried by younger alluvium in the valleys of eastern Contra Costa County (Table 3). A comparison of the soil humate ages in Figure 16 indicate that periods of pervasive landform stability occurred during: (1) the late Pleistocene (14,500 cal B.P.); (2) the early Holocene (8965 -

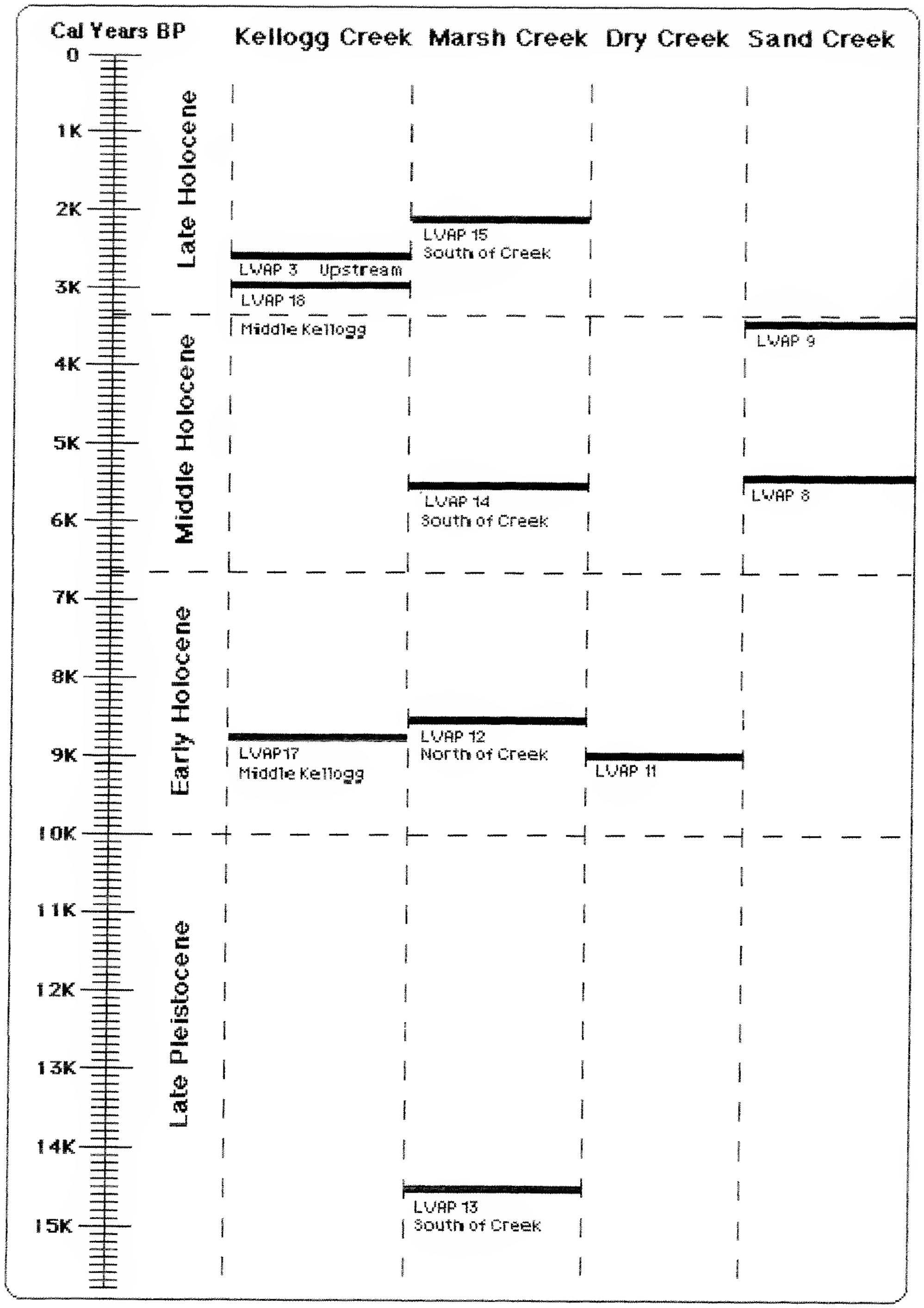


FIGURE 16. RADIOCARBON AGES FROM THE PIPELINE ROUTE. The correspondence in the age of deposits from different floodplains suggests that each had a similar depositional history. (All dates obtained from bulk soil humate samples, except LVAP 3 - obtained from wood charcoal)

8535 cal B.P.); (3) the middle Holocene (5530 - 5304 cal B.P.); and (4) the late Holocene (3460 - 2145 cal B.P.). These stable periods were interrupted by shorter episodes of landform instability that appear to coincide with intervals of environmental transition during (1) the late Pleistocene to early Holocene (10,000 B.P.); (2) the early to middle Holocene (7000 B.P.); and (3) the middle to late Holocene (3500 B.P.). Although there are slight variations in the timing of these processes, the similarity of the alluvial sequences suggests that the depositional histories of the floodplains are roughly synchronous (Figure 16).

Prolonged periods of soil formation (stable landform processes) were interrupted by shorter intervals of erosion or deposition (unstable landform processes) as illustrated in Figure 17. Extended periods of floodplain stability would have encouraged human landuse in the valleys, leading to the formation of archaeological sites. Shorter episodes of floodplain instability would have temporarily discouraged or disrupted human occupation in many valleys, and buried or destroyed evidence of previous occupations. Stable landscapes that were available for prehistoric settlement and material discard during the late Pleistocene and Holocene, were partially eroded and buried during subsequent unstable episodes. The alternation between stable and unstable landform processes has resulted in the differential preservation and/or visibility of archaeological materials associated with these past landscapes.

These findings indicate that the timing and extent of landscape evolution have exerted a profound influence on the structure of the archaeological record in the Los Vaqueros area. The recent discovery and analysis of artifacts from deeply buried site (CA-CCO-696) indicate that prehistoric people used the area during the early Holocene, significantly earlier than suggested by surface evidence alone (Meyer and Rosenthal 1996). Analysis also shows that archaeological materials from more than one cultural group and/or time is

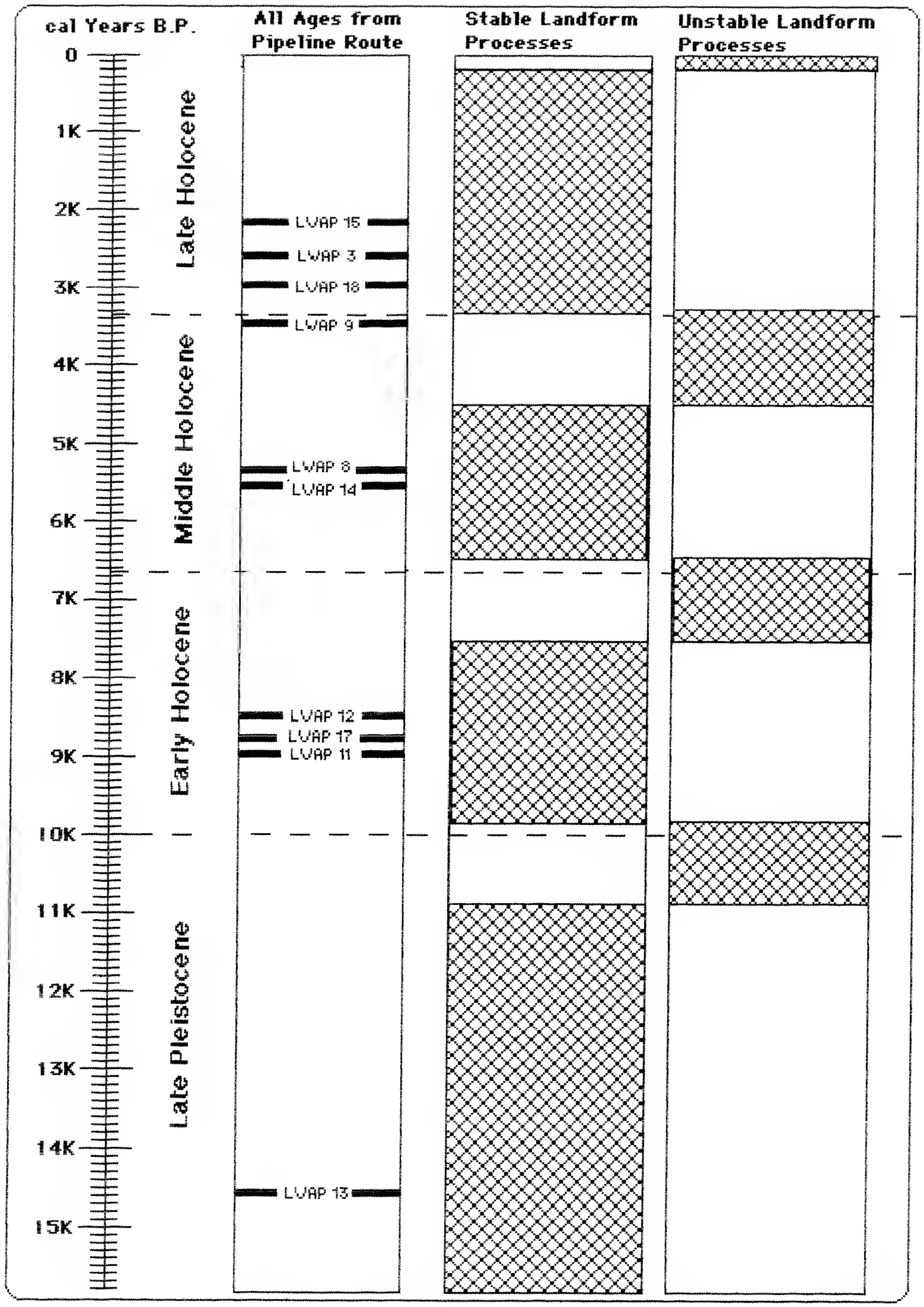


FIGURE 17. THE TIMING OF MAJOR LANDFORM PROCESSES.
Note that stable periods exceed unstable periods in duration.
(All radiocarbon ages obatined from bulk soil humate

superimposed on a single land surface (Vaqueros Paleosol) in the upper deposit at CA-CCO-696. Comparisons of alluvial sequences from valleys in eastern and western Contra Costa County demonstrate that they share roughly synchronous depositional histories. Similarities in the age of alluvial sequences found among widely separate valleys suggests that geological processes have structured the temporal range and spatial distribution of archaeological materials associated with these valleys.

Certain geological studies have recognized one or more depositional cycles in late Quaternary alluvium in the region (Atwater 1982; Lettis 1982, 1985, 1988; Marchand and Allwardt 1981). However, these studies usually lack sufficient age control for effective comparisons between separate areas. The temporal resolution provided by this study appears to represent one of the most thoroughly dated late Quaternary sequences in the region. Preliminary comparisons show that a general correlation exists between the findings of this study, and the previous stratigraphic and climatic sequences developed for the region (Figure 18). The depositional sequence identified in eastern Contra Costa County is similar to that identified in northeast San Joaquin Valley, which recognizes four distinct Holocene age allostratigraphic units (Marchand and Allwardt 1981). Likewise, there appears to be a strong correlation between the depositional record and the changes in the paleoenvironmental record of the region, particularly during the late Holocene (Curry 1968, 1969; Fullerton 1986; Moratto 1978; Scuderi 1984). The nature and timing of late Holocene deposition is remarkably similar to that found in the Walnut Creek Drainage of western Contra Costa County (Banks et al. 1984; Rogers 1988; Pape 1977).

Based on these regional correlation's, the depositional sequence identified by this study appears to reflect a series of climatically induced landscape changes that occurred throughout much of Central California. If

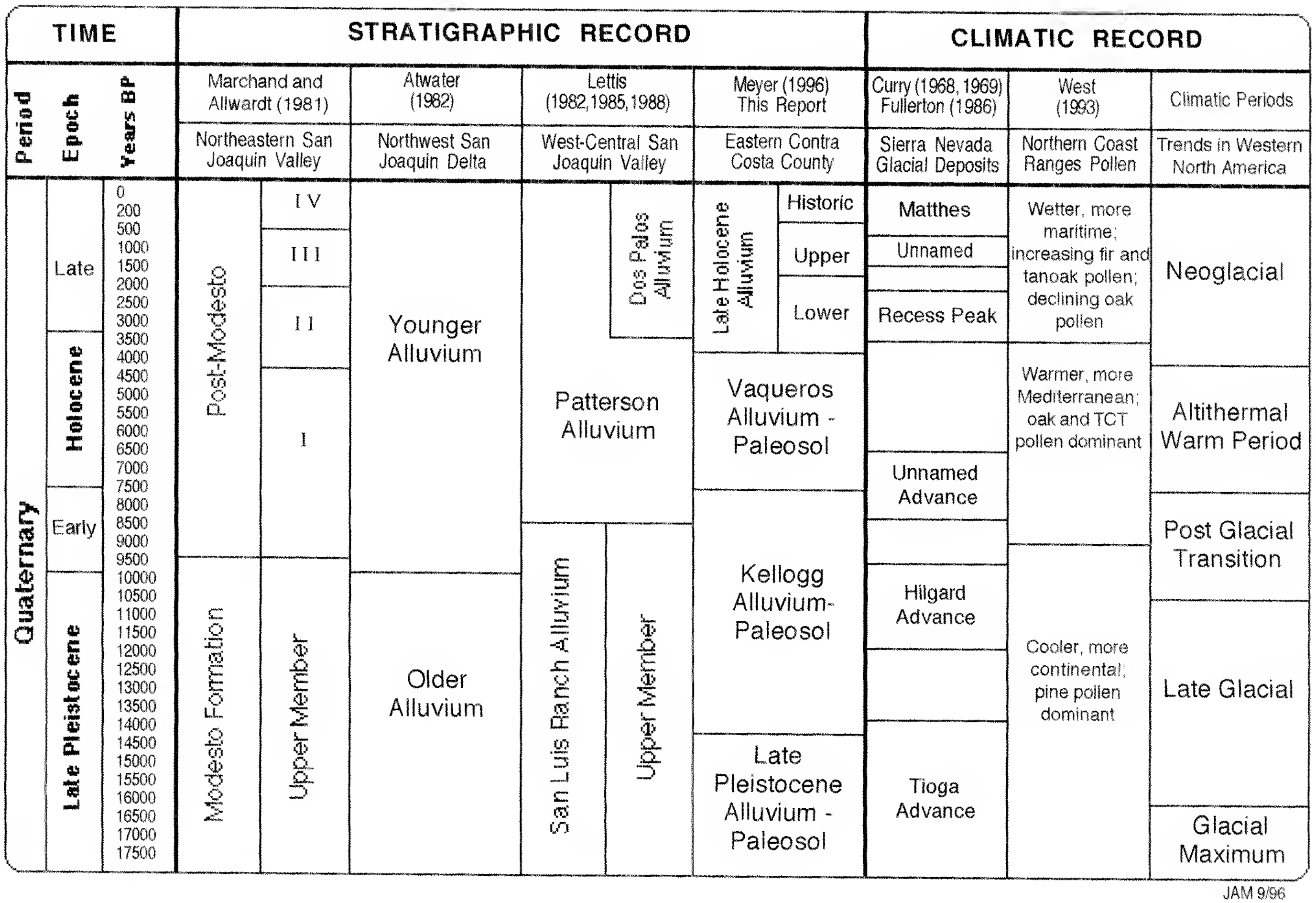


FIGURE 18. CORRELATION OF REGIONAL STRATIGRAPHIC AND CLIMATIC SEQUENCES

large-scale environmental changes were responsible for the formation of this sequence, then similar depositional sequences may be expected in other valleys of the region. If this is true, these findings are not unique to the Los Vaqueros area, but may be applied to other areas where similar conditions have prevailed.

This study has demonstrated that prehistoric settlement, subsistence, and demographic patterns cannot be inferred strictly from the distribution of surface sites in alluvial valleys. Instead, the nature and completeness of surface site distributions are the result of the same geological processes responsible for the evolution of the present landscape. Regional patterns of erosion and deposition have buried significant portions of the archaeological record in a way that can be identified, dated, and to some extent, predicted in Central California. Given these findings, the timing and magnitude of Holocene landscape change should be evaluated as an integral factor in determining the visibility and apparent distribution patterns of archaeological sites in this, and other regions of California.

APPENDIX A

LANDSCAPE SEGMENTS

The Pipeline Route was divided into 12 Landscape Segments as originally defined by Earth Sciences Associates (1992) and shown in Figure 5. The general extent of these segments is described below on the basis of geographic, geologic, and geomorphic characteristics.

The Upper Kellogg Creek segment includes the Kellogg Creek Valley that extends from the northern footprint of the proposed dam to just north of Vaqueros Farms. The upstream section consists of a narrow, hillslope-bounded valley with a northeasterly orientation that turns into a broader valley with an east-west orientation in the midstream section. The downstream section of the segment turns to a more northerly orientation where the valley again narrows. The segment contains a variety of alluvial, colluvial, and landslide deposits thought to be late Pleistocene to Holocene in age.

The Middle Kellogg Creek segment includes the area that extends northward from Vaqueros Farms across the valley occupied by the MacKenzie Ranch, to the point where Kellogg Creek passes under the former Vasco Road. The segment is a relatively broad, north south-trending valley that contains a gently sloping alluvial floodplain. The alluvium of this segment is thought to be late Pleistocene to Holocene in age.

The Camino Diablo Hillfront segment includes the area that extends northward from the point where Kellogg Creek passes under the former Vasco Road toward the intersection of Camino Diablo Road with Walnut Avenue. This segment consists of hillslopes that are underlain by Eocene age shale, claystone, and sandstone.

The Lower Kellogg Creek segment includes the area that extends northward from near the intersection of Camino Diablo with Walnut Avenue to the Los Vaqueros Transfer Facility, then northwesterly toward the Domengine Plateau. This segment consists of coalescing alluvial fans and alluvial floodplain deposits thought to be late Pleistocene to Holocene in age.

The Domengine Plateau segment includes the low hillslopes that divide the Marsh Creek drainage on the Northwest from the Kellogg Creek drainage to the Southeast. The segment mainly consists of Eocene-age shale, claystone, and sandstone rocks of the Meganos and Domengine formations and a few areas of younger alluvial and colluvial deposits.

The Marsh Creek segment includes the broad, relatively flat alluvial floodplain that extends from the Domengine Plateau northwestward to the Older Alluvial Hills. The alluvium in this segment is thought to be Holocene in age.

The Older Alluvial Hills segment includes the low, rolling hills that occur to the north and south of the Dry Creek floodplain. This segment consists of older alluvial floodplain deposits that have since been downcut to form abandoned terraces. These deposits contain many matrix-supported, subangular to subrounded chert and quartzite cobbles from the Franciscan Complex of Mount Diablo (Atwater 1982:5). As the name suggests, the alluvium exhibits a well-developed soil profile that is generally considered to be late Pleistocene in age or older.

The Balfour Road segment includes a portion of the relatively flat alluvial floodplain occupied by Dry Creek that lies between Older Alluvial Hills to the north and south, and a small portion of the Deer Creek valley. The alluvium in this segment is thought to be Holocene in age.

The Lone Tree Valley segment includes the broad, relatively flat alluvial floodplain occupied by Sand Creek between the Older Alluvial Hills to the south and the Wolfskill Foothills to the north. The alluvium in this segment is thought to be late Pleistocene to Holocene in age.

The Wolfskill Foothills segment includes the low hillslopes that extend from the Lone Tree Valley to the Neroly Blending Facility in the Lindsey Basin. The segment consists mainly of Pliocene-age claystone, siltstone, and sandstone, and lesser areas of younger alluvial and colluvial fan deposits.

The Lindsey Basin segment includes the relatively flat alluvial valley that surrounds the site of the proposed Neroly Blending Facility. The alluvium in this segment is thought to be late Pleistocene to Holocene in age.

The Wolfskill Uplands segment includes the hillslopes immediately to the west of the site of the proposed Neroly Blending Facility. The segment consists of Pliocene-age claystone, siltstone, and sandstone rocks.

APPENDIX B
DEPOSIT TYPES

Alluvium consists of floodplain sediments (including channel gravel) derived from local soil and bedrock sources that interfinger with colluvial deposits along valley margins. These deposits form gently sloping alluvial fans and relatively flat floodplains within the drainage basins along much of the Pipeline Route. These deposits usually exhibit weakly to moderately developed surface soils that may range from slightly more than 10,000 years to recent in age.

Colluvium consists of hillslope sediments derived from the downslope movement of weathered hillslope materials that interfinger with alluvial sediments along valley margins. Localized areas consist of landslide debris deposited by catastrophic hillslope failure. These deposits tend to accumulate as wedge-shaped landforms at the base of hillslopes and within bedrock swales or hollows. These deposits usually exhibit weakly to moderately developed soil profiles that may range from late Pleistocene to Holocene in age.

Soil consists of layers or horizons of mineral and/or organic materials of variable thickness that differ from the parent material in which they form (Birkeland, Machette, and Haller 1991). Soil formation is generally controlled by the interaction of parent material, topography, organisms, climate, and time. The degree and depth of soil formation are primarily determined by the amount of time and/or intensity of weathering that has occurred near the surface since deposition. The surface soils along the Pipeline Route may range from Pleistocene to Historic in age.

Soil Horizons are zones of accumulation or depletion caused by the in-place weathering of earth materials near the surface. For example, an A horizon is formed by the accumulation of organic materials at or near the soil surface. The process of leaching can remove clay, organics, or carbonates from the upper portion of a soil to produce an E horizon. The downward movement and accumulation (translocation) of clay or carbonate from upper horizons often forms a B horizon in the lower portions of a soil. Relatively unweathered parent material is known as a C horizon.

Weakly developed soil profiles exhibit relatively thin A horizons, unoxidized C horizons, and usually lack developed B horizons. Moderately developed soil profiles exhibit relatively clear A and B horizons and partially oxidized C horizons. Well-developed soil profiles exhibit relatively thick, distinct A and B horizons and completely oxidized C horizons. The degree and depth of horizon development within a soil are determined primarily by the amount of time and intensity of weathering near the surface (Birkeland, Machette, and Haller 1991).

Paleosols are soils that, due to burial by younger deposits, are no longer subject to near-surface weathering processes. Paleosols mark the presence of stable landforms that formerly made up the surface of the ground (Birkeland, Machette, and Haller 1991). The degree of profile development exhibited by a paleosol reflects the amount of time that a land surface remained stable and available for human settlement in the past. Further, the differential preservation of a paleosol may indicate the preservation potential of any associated archaeological materials. Paleosols along the Pipeline Route may range from Pleistocene to Historic in age.

APPENDIX C

LIST OF SUBSURFACE TEST TRENCHES

Landscape Segment	Section	Area	Trench
Upper Kellogg Creek	upstream	West Vasco	4-25-1
			4-25-2
			4-25-3
Upper Kellogg Creek	upstream	East Vasco	10-3-1
			8-10-2
			8-26-2
			Terrace
Upper Kellogg Creek	midstream	South Vasco	8-26-1
Middle Kellogg Creek		West Vasco	9-21-1
			9-21-2
			9-21-3
			9-21-4
			9-21-5
Lower Kellogg Creek		Camino & Walnut	Orchard
Marsh Creek		South Creek	9-22-1
			9-22-2
			9-22-3
		North Creek	8-25-1
			8-25-2
			8-25-3
			8-25-4
Balfour Road		Deer Creek	8-24-1
		Dry Creek	Tomato
		Older Hills	9-22-5
Sand Creek		Floodplain	9-23-1
		Creek Bank	9-23-2

APPENDIX D

SOIL AND SEDIMENT DESCRIPTIONS

Segment: Upper Kellogg Creek, upstream section

Location: CA-CCO-637, S27/W3

Landform: Holocene alluvial fan

Depth in cm	Soil Horizon	Description:
0-20	Ap	Brown (10YR 5/3) clay loam, dark grayish brown (10YR 4/2) moist; breaks into very coarse irregular clods; hard dry, friable moist, slightly sticky and slightly plastic wet; common fine active roots and insect holes; no HCl reaction; 6.3 pH; clear wavy boundary.
20-40	A	Dark grayish brown (10YR 4/2) silt loam, dark grayish brown (10YR 4/2) moist; moderate medium to coarse granular structure; hard dry, very friable moist, slightly sticky and slightly plastic wet; many fine active roots and insect holes; very weak HCl reaction; 7.0 pH; gradual smooth boundary.
40-60	AC	Dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak medium to coarse subangular blocky structure; hard dry, very friable moist, slightly sticky and slightly plastic wet; common fine active roots and insect holes; very few faint clay films coating ped faces; very weak HCl reaction; 7.3 pH; abrupt smooth boundary.
60-100	2Ab	Dark grayish brown (10YR 4/2) clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium to coarse subangular blocky structure; hard dry, very friable moist, sticky and slightly plastic wet; few fine active and inactive roots and insect holes; few to very few faint clay films coating and bridging grains; common dispersed charcoal and archaeological materials; very weak to weak HCl reaction; 7.7-7.9 pH; gradual wavy boundary.
100-120	2ABtjb	Brown (10YR 5/3) loam, brown (10YR 4/3) moist; moderate medium to coarse subangular blocky structure; hard dry, very friable moist, sticky and plastic wet; very few fine active roots and insect holes; common fine inactive roots and insect holes; few faint clay films coating and bridging grains; few powdery CaCo3 filaments and <10% soft Stage II CaCo3 nodules; strong HCl reaction; 8.1 pH; gradual smooth boundary.
120-150	2ABktb	Pale brown (10YR 6/3) loam to silt loam, brown (10YR 4/3) moist; moderate medium to coarse subangular blocky structure; hard dry, very friable moist, sticky and plastic wet; very few fine active roots and insect holes; common fine inactive roots and insect holes; few faint clay films coating and bridging grains; common powdery CaCo3 filaments and <25% soft Stage II CaCo3 nodules; very strong HCl reaction; 7.9 pH.

Segment: Upper Kellogg Creek, upstream section

Location: CA-CCO-447/H, 10-3-1

Landform: Middle to late Holocene alluvial floodplain/terrace

Depth in cm	Soil Horizon	Description:
0-90	A	Dark grayish brown (10YR 4/2) silty clay loam, very dark gray (10YR 3/1) moist; <10% dispersed rounded gravels up to 12 x 19 mm; moderate medium to coarse subangular blocky structure; slightly hard dry, very friable moist, sticky and plastic wet; many fine to medium active roots and insect holes; no HCl reaction; gradual smooth boundary.
90-170	Bk	Light olive brown (2.5Y 5/4) clay loam, olive brown (2.5Y 4/4) moist; <10% dispersed rounded gravels; moderate medium to coarse subangular blocky structure; hard dry, friable moist, sticky and plastic wet; common fine to medium active roots and insect holes; many CaCo3 filaments coating holes and pores; <10% brown manganese mottles; very few faint clay films coating and bridging grains; very strong HCl reaction; gradual smooth boundary.
170-225	BCk	Olive brown (2.5Y 6/6) sandy loam, olive brown (2.5Y 4/4) moist; 25% poorly sorted rounded gravels up to 21 X 48 mm; massive structure; slightly hard dry, loose moist, non-sticky and non-plastic wet; very few fine active roots and insect holes; many inactive fine to medium roots and insect holes; common CaCo3 filaments coating holes and pores; very strong HCl reaction; abrupt wavy boundary.
225-300	2Btb	Olive brown (2.5Y 6/6) clay loam, olive brown (2.5Y 4/4) moist; <10% dispersed rounded gravels up to 22 x 42 mm; moderate medium to coarse subangular blocky structure; very hard dry, firm moist, sticky and plastic wet; many fine to medium in active roots and insect holes; <25% orange iron oxide mottles; few faint clay films coating and bridging grains; very strong HCl reaction.

Segment: Upper Kellogg Creek, upstream section

Location: CA-CCO-447/H, Terrace Trench

Landform: Historic alluvial terrace

Depth in cm	Soil Horizon	Description:
0-50	AC	Light olive brown (2.5Y 5/4) silt loam, olive brown (2.5Y 4/4) moist; <10 % dispersed rounded gravels up to 7 X 11 mm; weak medium granular structure; slightly hard dry, very friable moist, slightly sticky and slightly plastic wet; strong HCl reaction; abrupt wavy boundary
60-80	2BCk	Olive brown (2.5Y 6/6) sandy loam, olive brown (2.5Y 4/4) moist; 25% poorly sorted rounded gravels up to 21 X 48 mm; massive structure; slightly hard dry, loose moist, non-sticky and non-plastic wet; very few fine active roots and insect holes; many inactive fine to medium roots and insect holes; common CaCo3 filaments coating holes and pores; very strong HCl reaction; abrupt wavy boundary.
80-130	3Btb	Olive brown (2.5Y 6/6) clay loam, olive brown (2.5Y 4/4) moist; <10% dispersed rounded gravels up to 22 x 42 mm; moderate medium to coarse subangular blocky structure; very hard dry, firm moist, sticky and plastic wet; many fine to medium in active roots and insect holes; <25% orange iron oxide mottles; few faint clay films coating and bridging grains; very strong HCl reaction.

Segment: Upper Kellogg Creek, midstream section

Location: CA-CCO-446H, Trench 8-26-1

Landform: Late Pleistocene alluvial terrace

Depth in cm	Soil Horizon	Description:
0-50	A	Yellowish brown (10YR 5/4) loam. dark yellow brown (10YR 4/4) moist; <10% dispersed subrounded to rounded gravels up to 17 x 30 mm; moderate medium to coarse angular blocky structure; very hard dry, firm moist, sticky and plastic wet; common fine active roots and insect holes; few faint clay films coating and bridging grains; no HCl reaction; 6.6 pH; gradual smooth boundary.
50-140	Btk	Yellowish brown (10YR 5/6) loam, yellowish brown (10YR 5/8) moist; <10% dispersed subrounded to rounded gravels; strong medium to coarse angular blocky structure; very hard dry, firm moist, sticky and plastic wet; few fine active roots and insect holes; common distinct clay films coating ped faces and bridging grains; common CaCo3 filaments coating ped faces; strong to very strong HCl reaction; 8.2 pH; clear wavy boundary.
140-250	BCk	Brownish yellow (10YR 6/6) sandy clay loam, yellowish brown (10YR 5/6) moist; 50% moderately sorted and imbricated subrounded to rounded gravels up to 10 x 20 mm; moderate medium to coarse angular blocky structure; hard dry, very friable moist, slightly sticky and slightly plastic wet; few fine active roots and insect holes; few faint clay films coating and bridging grains; common CaCo3 filaments coating ped faces; weak to strong HCl reaction: 8.1 pH; abrupt wavy boundary.
250-270	2Bkyb	Brownish yellow (10YR 6/6) sandy clay loam, yellowish brown (10YR 5/6) moist; >75% clast supported, poorly sorted subrounded to rounded gravels up to 57 x 81 mm; massive structure; extremely hard dry, very firm moist, non-sticky and non-slightly plastic wet; many distinct gypsum crystals; > 40% Stage III+ CaCo3 coating, bridging, and cementing grains and clasts; very strong HCl reaction; 8.4 pH.

Segment: Upper Kellogg Creek, midstream section

Location: CA-CCO-446H, Trench 8-26-1

Landform: Historic alluvial terrace

Depth in cm	Soil Horizon	Description:
0-120	AC	Light olive brown (2.5Y 5/4) loam, olive brown (2.5Y 4/3) moist: weak very coarse granular structure; slightly hard dry, very friable moist, slightly sticky and slightly plastic wet; many fine active roots and insect holes: few dispersed historic materials (glass, cow tooth, etc.); weak HCl reaction; 7.7 pH; inset and overlying late Pleistocene terrace.

Segment: Middle Kellogg Creek

Location: Trench 9-21-1

Landform: Late Pleistocene alluvial terrace remnant

Depth in cm	Soil Horizon	Description:
0-45	A	Light olive brown (2.5Y 5/3) loam. dark olive brown (2.5Y 3/3) moist; moderate fine to medium granular structure; hard dry, friable moist, slightly sticky and slightly plastic wet; many fine and medium active roots and insect holes; few firm CaCo3 nodules; no HCl reaction, except for nodules; 7.3 pH; clear wavy boundary.
45-60	Bk	Light olive brown (2.5Y 5/3) loam, olive brown (2.5Y 4/4) moist; moderate fine to coarse subangular blocky structure; hard dry, friable moist, sticky and plastic wet; common fine and medium active roots and insect holes; many powdery Stage I CaCo3 filaments coating ped faces and holes; strong HCl reaction; 7.6 pH; clear wavy boundary.
60-200	Bktj	Light olive brown (2.5Y 5/3) loam to sandy clay loam, olive brown (2.5Y 4/4) moist; moderate fine to coarse subangular blocky structure; hard dry, friable moist, sticky and plastic wet; common fine and medium active roots and insect holes; very few faint clay films coating and bridging grains; many powdery Stage I CaCo3 filaments coating ped faces and holes; 15% firm Stage II+ CaCo3 nodules; strong HCl reaction; 7.8 pH; abrupt wavy boundary.
200-400	BCt	Light yellowish brown (2.5Y 6/4) loam, light olive brown (2.5Y 5/4) moist; >75% clast supported, weakly sorted rounded to well-rounded gravels up to 49 x 67 mm (90% sandstone, 10% chert; massive structure; slightly hard dry, very friable moist, non-sticky and non-plastic wet; few fine and medium active roots and insect holes; few faint clay films coating ped faces and bridging grains; many powdery Stage I CaCo3 filaments coating ped faces and holes; slight HCl reaction; 8.1 pH.

Segment: Middle Kellogg Creek

Location: Trench 9-21-5

Landform: Early to late Holocene alluvial floodplain

Depth in cm	Soil Horizon	Description:
0-60	A	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist: weak medium granular structure; hard dry, firm moist, sticky and plastic wet; common fine active roots and insect holes; no HCl reaction; 6.6 pH; gradual smooth boundary.
60-110	Btj	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; weak medium to coarse subangular blocky structure; very hard dry, very firm moist, sticky and very plastic wet; few fine active roots and insect holes; few faint clay films coating ped faces and bridging grains; very weak HCl reaction; 6.8 pH; clear smooth boundary; C14 = 2880 +/- 80 B.P.
110-160	2ABtkb	Brown (10YR 5/3) silt loam, dark brown (10YR 4/3) moist; moderate medium to coarse prismatic angular blocky structure; very hard dry, very firm moist, sticky and plastic wet; very few fine active roots and insect holes; many fine inactive roots and insect holes; few distinct clay films coating ped faces and bridging grains: few firm Stage II CaCo3 nodules; no HCl reaction, except nodules strong; 8.0 pH; clear smooth boundary.
160-220	2Btkb	Yellowish brown (10YR 5/4) loam, dark yellowish brown (10YR 4/4) moist; moderate medium to coarse prismatic subangular blocky structure; slightly hard dry, very friable moist, sticky and slightly plastic wet; common fine to medium inactive roots and insect holes; common distinct clay films coating holes and bridging grains; common firm Stage II CaCo3 nodules; weak HCl reaction, except nodules strong; 8.0 pH; C14 = 7980 +/- 130 B.P.

Segment: Marsh Creek

Location: South of creek, Trench 9-22-1

Landform: Late Pleistocene to late Holocene alluvial floodplain

Depth in cm	Soil Horizon	Description:
0-90	A	Light olive brown (2.5Y 5/3) loam, dark grayish brown (2.5Y 4/2) moist; weak fine granular structure; hard dry, friable moist, slightly sticky and slightly plastic wet; many fine and medium active roots and insect holes; no HCl reaction; 7.8 pH; gradual smooth boundary.
90-140	Bk	Light olive brown (2.5Y 5/4) loam, olive brown (2.5Y 4/3) moist; weak very coarse subangular blocky structure; slightly hard dry, very friable moist, slightly sticky and slightly plastic wet; common fine and medium active roots and insect holes: common powdery Stage I CaCo3 filaments coating ped faces and holes; strong HCl reaction; 8.0 pH; clear wavy boundary; C14= 2180 +/- 70 B.P.
140-270	2ABkb	Light olive brown (2.5Y 5/4) silt loam, dark olive brown (2.5Y 3/3) moist; moderate medium to coarse prismatic angular blocky structure; hard dry, friable moist, sticky and plastic wet; common fine inactive roots and insect holes; very few faint clay films coating and bridging grains; common Stage I+ CaCo3 filaments coating pores and holes; weak HCl reaction; 8.1 pH; clear smooth boundary; C14= 4760 +/- 70 B.P.
270-400	3ABktb	Light olive brown (2.5Y 5/4) silt loam, olive brown (2.5Y 4/3) moist; moderate fine to medium angular blocky structure; slightly hard dry, friable moist, sticky and plastic wet: many fine to medium inactive roots and insect holes; few distinct clay films coating ped faces and bridging grains; common Stage I+ CaCo3 filaments coating pores and holes; weak HCl reaction; 8.1 pH; C14= 12400 +/- 150 B.P.

Segment: Marsh Creek

Location: North of creek, Trench 3

Landform: Late Pleistocene to late Holocene alluvial floodplain

Depth in cm	Soil Horizon	Description:
0-120	A	Yellowish brown (10YR 5/6) loam, dark yellowish brown (10YR 3/3) moist; <10% dispersed rounded gravels up to 12 x 25 mm; moderate fine to medium granular structure; hard dry, friable moist, sticky and plastic wet; many fine active roots and insect holes; very weak HCl reaction; 7.4 pH; clear smooth boundary.
120-180	2ABtb	Yellowish brown (10YR 5/6) loam, dark yellowish brown (10YR 4/6) moist; 10% dispersed subrounded to rounded gravels up to 12 x 18 mm; strong fine to medium angular blocky structure; slightly hard dry, friable moist, sticky and plastic wet; few fine active roots and insect holes; many fine to medium inactive roots and holes; common distinct clay films coating ped faces and bridging grains; no HCl reaction; 7.5 pH; abrupt smooth boundary; C14= 7810 +/-220 B.P.
180-200	3BCtb	Strong brown (7.5YR 4/6) sandy loam, dark yellowish brown (10YR 4/4) moist; 50% poorly sorted subrounded to rounded gravels up to 58 x 78 mm; moderate fine to medium angular blocky structure; slightly hard dry, friable moist, sticky and slightly plastic wet; no roots or holes; many distinct clay films coating ped faces and bridging grains; very weak HCl reaction; 7.6 pH.

Segment: Balfour Road

Location: Dry Creek, Trench 9-22-4

Landform: Pleistocene to early Holocene alluvial fan

Depth in cm	Soil Horizon	Description:
0-12	Ap	Very dark grayish brown (10YR 3/2) clay, very dark grayish brown (10YR 3/2) moist; 10% dispersed subrounded to rounded gravels; moderate medium to coarse angular blocky structure with few slickensides on ped faces; hard dry, friable moist, sticky and plastic wet; common fine to medium active roots and insect holes; no HCl reaction; 6.9 pH; clear smooth boundary.
12-40	Bk	Dark grayish brown (10YR 4/2) silt loam, dark grayish brown (10YR 4/2) moist; <10% dispersed subrounded to rounded gravels; moderate medium to coarse prismatic angular blocky structure; hard dry, friable moist, sticky and plastic wet; few fine active roots and insect holes; very few faint clay films coating ped faces; many Stage 1+ CaCo3 filaments coating inactive root holes; strong HCl reaction; 8.0 pH; clear smooth boundary; C14= 8050 +/- 80 B.P.
40-55	Btj	Brown (10YR 4/3) silt loam, dark yellowish brown (10YR 4/4) moist; <10% dispersed subrounded to rounded gravels; moderate medium to coarse prismatic angular blocky structure; slightly hard dry, friable moist, sticky and plastic wet; few fine active roots and insect holes; very few distinct clay films coating ped faces and pores; weak HCl reaction; 8.2 pH; clear smooth boundary.
55-100	BCt	Yellowish brown (10YR 4/3) loam, dark yellowish brown (10YR 4/4) moist; 10% dispersed subrounded to rounded gravels; weak very coarse subangular blocky structure; hard dry, friable moist, slightly sticky and slightly plastic wet; very few fine active roots and insect holes; few distinct clay films coating holes and bridging grains; very weak HCl reaction; 8.1 pH; clear wavy boundary.
100-110	2BCtb	Yellowish brown (10YR 4/3) loam, dark yellowish brown (10YR 4/4) moist; 50% dispersed subrounded to rounded gravels up to 42 x 60 mm (chert, basalt, quartzite); weak very coarse subangular blocky structure; hard dry, friable moist, slightly sticky and slightly plastic wet; very few fine active roots and insect holes; few distinct clay films coating holes and bridging grains; no HCl reaction; 7.8 pH; abrupt wavy boundary.
110-140	3ABtb	Yellowish brown (10YR 4/3) clay, dark yellowish brown (10YR 4/4) moist; strong fine to medium angular blocky structure with few slickensides on ped faces; hard dry, firm moist, very sticky and very plastic wet; common fine inactive roots and insect holes; many prominent clay films coating ped faces, holes and grains; no HCl reaction; 7.7 pH; clear smooth boundary.

continued;

140-160	3Btk	Yellowish brown (10YR 4/3) clay, dark yellowish brown (10YR 4/4) moist; 25% dispersed subrounded to rounded gravels up to 35 x 60 mm (chert, basalt, quartzite); strong fine to medium angular blocky structure; hard dry, firm moist, sticky and plastic wet; common fine inactive roots and insect holes; many prominent clay films coating ped faces, holes and grains; many hard Stage III $CaCo_3$ nodules up to 22 x 22 mm; strong HCl reaction on nodules; 7.9 pH; clear smooth boundary.
160-210	3Btb	Yellowish brown (10YR 4/3) clay, dark yellowish brown (10YR 4/4) moist; 10% dispersed subrounded to rounded gravels (chert, basalt, quartzite); strong fine to medium angular blocky structure; very hard dry, firm moist, very sticky and very plastic wet; common fine inactive roots and insect holes; many prominent clay films coating ped faces, holes and grains; few hard Stage III $CaCo_3$ nodules; strong HCl reaction; 8.1 pH.

Segment: Balfour Road

Location: Dry Creek, "Tomato Trench"

Landform: Early to late Holocene alluvial floodplain

Depth in cm	Soil Horizon	Description:
0-380	AC	Olive yellow (2.5Y 6/6) silt loam, light olive brown (2.5Y 5/6) moist; massive structure, breaks into very coarse irregular clods; hard dry, friable moist, slightly sticky and slightly plastic wet; common fine active roots and insect holes; strong HCl reaction; abrupt wavy boundary overlying early Holocene paleosol at 600 cm.

Segment: Lone Tree Valley

Location: Sand Creek floodplain, Trench 9-23-1

Landform: Early to late Holocene alluvial floodplain

Depth in cm	Soil Horizon	Description:
0-60	A	Dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; massive structure, breaks into very coarse irregular clods; hard dry, friable moist, slightly sticky and slightly plastic wet; common fine active roots and insect holes; no HCl reaction; 6.9 pH; clear smooth boundary.
60-100	Btj	Brown (10YR 5/3) clay loam, brown (10YR 4/3) moist; moderate coarse prismatic subangular blocky structure; hard dry, friable moist, sticky and plastic wet; few fine active roots and insect holes; few faint clay films coating ped faces and pores; no HCl reaction; 7.7 pH; clear smooth boundary; C14= 3270 +/- 80 B.P.
100-150	Btk	Brown (10YR 5/3) clay loam, brown (10YR 4/3) moist; moderate coarse prismatic angular blocky structure; hard dry, friable moist. sticky and plastic wet; common fine active roots and insect holes; few distinct clay films coating and bridging grains; common powdery Stage I CaCo3 filaments coating holes; moderate to strong HCl reaction; 7.9 pH; clear smooth boundary.
150-220	Cox	Light olive brown (2.5Y 5/4) clay loam, olive brown (2.5Y 4/4) moist; massive structure, breaks into irregular clods; hard dry, very friable moist, sticky and slightly plastic wet; very few fine active roots and insect holes; very few distinct clay films coating inactive root holes; few powdery Stage I CaCo3 filaments coating holes; weak to moderate HCl reaction; 8.1 pH; abrupt smooth boundary.
220-440	2ABtkb	Light olive brown (2.5Y 4/3) clay loam, dark grayish brown (2.5Y 4/2) moist; moderate medium to coarse subangular blocky structure; hard dry, friable moist, sticky and plastic wet; common fine inactive roots and insect holes; common distinct clay films coating ped faces, holes, and grains; common soft Stage I+ CaCo3 filaments coating holes; strong HCl reaction; 8.1 pH; abrupt smooth boundary; C14= 4620 +/- 70 B.P.
440-450	2ABtkb	Light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; moderate medium to coarse angular blocky structure; hard dry, friable moist, sticky and plastic wet; common fine in active roots and insect holes; common distinct clay films coating ped faces, holes, and bridging grains; common soft Stage I+ CaCo3 filaments coating holes; moderate to strong HCl reaction; 8.0 pH.

Segment: Lone Tree Valley

Location: Sand Creek bank, Trench 9-23-2

Landform: Early to late Holocene alluvial floodplain

Depth in cm	Soil Horizon	Description:
0-40	A	Light olive brown (2.5Y 5/3) loam, olive brown (2.5Y 4/3) moist; weak very fine to fine granular structure: hard dry, friable moist, slightly sticky and plastic wet; common fine active roots and insect holes; upper 20 cm plow zone; no HCl reaction; 6.0 pH; clear smooth boundary.
40-80	C	Light olive brown (2.5Y 5/4) loam, olive brown (2.5Y 4/4) moist; massive structure, exhibits vertical stratification; slightly hard dry, very friable moist, slightly sticky and slightly plastic wet; common fine active roots and insect holes; very weak HCl reaction; 7.9 pH; clear smooth boundary.
80-230	2Ab	Dark grayish brown (2.5Y 4/2) loam, very dark grayish brown (2.5Y 3/2) moist; moderate medium to coarse angular blocky structure with slickensides on ped faces; very hard dry, firm moist, sticky and plastic wet; common fine active roots and insect holes; few powdery Stage I CaCo3 filaments coating root holes; weak to moderate HCl reaction; 8.0 pH; gradual smooth boundary.
230-450	2Bkb	Light olive brown (2.5Y 5/3) loam, olive brown (2.5Y 4/3) moist; moderate medium to coarse subangular blocky structure, lower 150 cm sandy and massive; hard dry, friable moist, sticky and plastic wet; few fine active roots and insect holes; very few clay films coating ped faces and pores; common soft Stage I+ CaCo3 filaments coating root holes; moderate HCl reaction; 8.1 pH; abrupt smooth boundary.
450	3ABtb	Light yellowish brown (10YR 6/4) loam, yellowish brown (10YR 5/6) moist; moderate medium to coarse angular blocky structure; hard dry, friable moist, sticky and plastic wet; many fine to medium inactive roots and insect holes; few distinct clay films coating ped faces and pores; few soft Stage I+ CaCo3 filaments coating inactive holes; weak to moderate HCl reaction; 7.8 pH.

APPENDIX E

RADIOCARBON SAMPLE DATA

LVAP	Beta-	Measured C14 Age B.P.	C13/12 Ratio	Conventional C14 Age B.P.	Comment:
3	77470	2520 +/- 100	-26.7	2500 +/- 100	low carbon sediment and charcoal
7	79399	NA	NA	NA	insufficient carbon - not tested
8	79400	4620 +/- 70	-26.7	4590 +/- 70	low carbon sediment - soil humate
9	79401	3270 +/- 80	-26.3	3250 +/- 80	low carbon sediment - soil humate
10	79402	NA	NA	NA	insufficient carbon - not tested
11	79403	8090 +/- 80	-27.1	8050 +/- 80	low carbon sediment - soil humate
12	79404	7820 +/-220	-25.5	7810 +/- 220	low carbon sediment - soil humate
13	79405	12410 +/- 150	-26.0	12400 +/- 150	low carbon sediment - soil humate
14	79406	4790 +/- 70	-26.4	4760 +/- 70	low carbon sediment - soil humate
15	79407	2180 +/- 70	-24.7	2180 +/- 70	low carbon sediment - soil humate
16	79408	NA	NA	NA	insufficient carbon - not tested
17	78409	7990 +/- 130	-25.9	7980 +/- 130	low carbon sediment - soil humate
18	78410	2900 +/- 80	-25.9	2880 +/- 80	low carbon sediment - soil humate

Based on analyses performed by Beta Analytic, Inc., Miami Florida.

APPENDIX F

ARCHAEOLOGICAL RESOURCE RECOMMENDATIONS

The following recommendations are provided for the protection and management of any prehistoric archaeological resources along the Pipeline Route:

1. It is recommended that further archaeological observation be conducted during construction of the Pipeline Route in areas identified in Table 4 as having a low to high potential for buried archaeological materials as shown in Figure 15 (see Table 5 for specific station numbers). The only area identified as having a moderate to high potential is a small part of the upstream section in the Upper Kellogg Creek Segment (CA-CCO-637). An archaeologist should periodically observe construction activities to determine if buried deposits have been exposed in these areas.

2. If archaeological resources (buried or otherwise) are encountered in the course of project activities, work shall be halted and relocated 60 m (200 feet) from the area of the initial discovery.

3. If archaeological resources are recognized, identification of the property type represented and an assessment of the site's extent and integrity will be made in the field by the archaeologist. For further details, see the Historic Property Treatment Plan for Late Discoveries (SSUAF 1995).

4. If human remains are encountered, State law requires that the County Coroner be notified immediately. The CCWD would then implement the conditions of the CCWD's Memorandum of Understanding with the Most Likely Descendants. Section 7050.5 of the California Health and Safety Code states that it is a misdemeanor to knowingly disturb a human burial.

TABLE 5. List of Locations With Buried Archaeological Potential

Landscape Segment	Section or Area	LV30 Sheet:	Station No.
Los Vaqueros Pipeline:			
Lone Tree Valley	Sand Creek	LP-C-09-11	87+00 - 125+20
	Sand Creek	LP-C-12-17	126+76 - 204+00
Balfour Road	Dry Creek	LP-C-20-22	244+00 - 275+00
Marsh Creek	North of Creek	LP-C-28	355+00 - 361+20
	South of Creek	LP-C-28-30	363+60 - 387+00
Lower Kellogg	West of Walnut Ave.	LP-C-33-35	424+00 - 457+00
Transfer Pipeline:			
Lower Kellogg	Camino Diablo	TP-C-02-03	33+34 - 47+50
Middle Kellogg	West of Vasco Road	TP-C-04-07	56+00 - 109+00
Upper Kellogg	Downstream	TP-C-08-09	115+00 - 130+00
	Upstream, CCO-637	See LV-10, OW-1	Keiwit Segment

NOTE: LV30 Sheet and Station Numbers adapted from Montgomery and Watson (1994).

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